00088510

BOMBAY BRANCH
OF THE
ROYAL ASIATIC SOCIETY.
TOWN HALL, BOMBAY.

Digitized with financial assistance from the
Government of Maharashtra
on 02 January, 2016

THE

CAUSE OF DRY ROT.

LONDON:
PRINTED BY THOMAS DAVISON, WHITEFRIARS.

THE

CAUSE OF DRY ROT

DISCOVERED:

WITH A DESCRIPTION

OF

A Patent-Invention,

FOR

PRESERVING DECKED VESSELS

FROM

DRY ROT,

AND

88510

GOODS ON BOARD

FROM

DAMAGE BY HEAT.

BY

JOHN GEORGE, ESQUIRE,

BARRISTER AT LAW.

LONDON:

PRINTED FOR LONGMAN, REES, ORME, BROWN, AND GREEN,
PATERNOSTER-ROW.

1829

691.12
Esq/Cam
88510

CONTENTS.

CHAPTER I.

The cause of dry rot stated, with the circumstances of its discovery. The quick passage of heat through the timber is the cause. Introductory observations on the objects of the work. An underground vault of the author described. A large quantity of heat required to enter or leave it sensibly to alter its temperature. A new door put up in it. The changes of temperature of the vault with the changes of the seasons. The new door becomes dry rotten. Inquiries into the cause. Various possible causes considered and rejected. The true cause discovered. Page 1

CHAPTER II.

Arguments that the assigned cause of dry rot is the true cause. A large quantity of heat passed through the vault door while it was dry rotting. The proof of this, on various grounds. The property of heat to pass through substances towards equalizing temperatures. The quantity that passes does not depend on the absolute height of the temperature, but on the difference of the temperatures on the opposite sides of the substance passed through, and on the nature of the substance, and other considerations. Argument that a large quantity of heat passed through the door from a very large quantity having alternately entered and left the vault. A further argument, from the slowness with which heat can pass down-

wards through a body of air, and from the thinness of the door compared with the thickness of the brickwork. Two circumstances conclusive as to the fact: first, the depositing of water against the outside of the door on the approach of warm weather, by the heat, which kept it suspended in the air, leaving the air in order to pass through the door; secondly, the converse of the first, in the depositing of water against the inner side of the door on the coming of cold weather. Why the water is so deposited, and in such large quantities as alleged. An occasion on which much heat was caused to pass out through the crown of the arch, attended with the like depositing of water. The vault door set open on the first frost of an autumn, and a strong current of air into the vault at the lower part, and out of it at the upper part of the door-way immediately taking place. The cause of the current. A further instance of the depositing of water, on heat leaving the air to pass through a colder substance. A circulation of air is constantly going on in a close shut vault, while heat is entering or leaving it. Water taken up from the inner side of the vault door on the entering of heat is quickly deposited again on the colder bottles of wine in the vault, and on the highest bottles first. Page 14

CHAPTER III.

Further arguments that the cause assigned is the true cause of dry rot. None of the other supposed causes before mentioned the real cause. Another possible cause supposed and rejected. Cases of what is sometimes called wet rot instanced, with a conjecture as to its cause. The necessity, in general, of a current of heat through the timber, to cause dry rot. A possible objection to the assigned cause of dry rot anticipated and answered. Various instances of the effects of the quick entrance or passing off of heat into and from different kinds of substances. Conjecture as to how the cause assigned works the decay. Fungus, or insects, not the cause, nor always present. Fungus when present may hasten the progress of the decay, and how. Page 32

CHAPTER IV.

The current of heat through the timber must be more or less rapid or considerable, and its action be continued in the whole a considerable time. Why dry rot is comparatively so seldom found in rooms having fire places in them. Comparatively new houses more subject to dry rot than older ones, and why. The quicker passage of heat through moist air. Why the more central parts of a piece of timber may be dry rotted before the more outward parts. Page 50

CHAPTER V.

The kind of situations in which timber must be placed in order to have a current of heat passing through it. The principal circumstances on which the quantity that passes depends. The progress of the decay dependent on the rapidity of the passage of the heat, and the length of time it passes, and on the kind and quality of the timber. Circumstances on which the superior quality of timber, for its kind, appears to depend. Page 58

CHAPTER VI.

Shipping is peculiarly exposed to the action of the alleged cause of dry rot. How soon a ship whilst building begins to be exposed to it, and why. A vessel is the more exposed to it, the closer it is kept shut. Also, the larger the vessel. So likewise by being coppered. So by having a heating cargo or a numerous crew on board. The upper works and parts near the water-line are exposed to the greatest differences of temperature, and they decay the soonest. The floor timbers are the least exposed, and they remain sound. Page 65

CHAPTER VII.

Of the proper nature of the remedy for the evil of dry rot, &c. with preliminary matters; and of the principles of the author's patent invention. The circumstances that decided him on undertaking the subject. The rapid decay of ships in the navy. Particular anecdotes of. Phenomena of dry rot hitherto inexplicable. King's ships sometimes cross the ocean home with their quarterdecks rocking like new made hayricks. A trial at law, arising from a merchant ship having quickly become dry rotten. The acknowledged ignorance of the parties of the true cause of dry rot. Motion in the House of Commons for the "Navy Estimates." The admitted heavy charges in them for "materials" and "artificers' wages." The rapid decay of the vessels attributed by the mover to a mistaken cause. Contrivances that might prove palliatives, but only palliatives, of the evil. Another kind of palliative in theory, but unsafe. A quality essential to the proper remedy. The principles of the writer's patent invention for preserving decked shipping from dry rot, &c. Its leading principle is to keep what approximation of temperatures to an equilibrium, where, and by what means. Why this is made the leading principle. A supply and change of air, the means used, and why. The supply or quantity to be a regulated supply, and why. The means provided of introducing the air only into particular parts of the vessels, and down only to particular depths at pleasure. Page 73

CHAPTER VIII.

Commencement of the description of the invention itself. It consists of a combination of alterations in the vessels, and of apparatus and machinery. The alterations in the vessels consist of additional openings, where, and for what purposes. The apparatus and machinery are for ascertaining the temperatures, and introducing and passing off hotter or colder air, when and where. For introducing, in general, colder

air, a hollow shaft, with a moveable part to stand when raised above deck, &c. Apertures in the moveable part, with sliding shutters, to admit the air and regulate the quantity. The shaft, where situated. The colder air to be conveyed, down to what level. Hollow trunks attached to the shaft, for conveying the air whither required. Different orifices in the trunks, with hatches to regulate the passages for the air. When an additional set of trunks. The apparatus described not alone sufficient for what purposes. To ensure the right current of air, a new invented valve. The material of its working part. The valve where placed. The moving force for putting it in action. The before described apparatus will not always act, and when not, other means, after mentioned, resorted to. Apertures for discharging the heated air. Chimnies placed over them. Revolving chimney tops, to discharge the air in the direction of the wind. For getting at valves in long voyages, &c. open lattice works, with a folding rod, for passing the valves up and down. For goods liable to damage by heat, perforated battens to preserve passages for the air. To ascertain the temperatures, thermometers kept placed where. Grooves for letting them down to the assigned stations. Ascertaining the temperatures of the water, at what different depths. The removal of heavy gases from the interior. Page 83

CHAPTER IX.

The description of the invention concluded. Warmer air introduced by removing the colder, and means provided of introducing it at pleasure, to particular parts and levels only, and in regulated quantities to each level. A descending hollow trunk furnished with apertures at different depths, with the means of closing them completely or to any partial extent. The colder air to be removed up through the trunk by any adequate means, as, a pump, &c. The air removed discharged, where. The pump, &c. to be sufficiently large for the removal of colder air to keep pace with what. A hose attached to each side of the descending trunk, fore and aft, for what purpose.

What to be done on introducing warmer air. General rules on introducing and passing off air, whether colder or warmer. When to keep the temperature of the interior a little the higher, and why. The air within to be kept as dry as practicable, and why. Subject to what precaution, the interior, for the comfort of the persons on board, may be kept of considerably the higher temperature. By means of one part or the other of the invention, the outer air, whether colder or warmer (the safety of the vessel permitting), may always be introduced and passed off again in any required quantity, to and from any parts where required. And by means of it, the desired approximation of temperatures may, in general, be maintained. One exception only known to the author, and in it the complete attainment of the object sought, an impossibility. But in the excepted case, the force of the current of heat may be mitigated and divided among different pieces of timber in succession, and be rendered little hurtful. The invention, however, on this account, only represented as having the limited power of attaining the proposed objects, as often and as far as practicable by the means used. But these means more effectual than any others. Page 103

CHAPTER X.

Of the motives for putting the author's invention in practice. The necessity of providing a remedy for the evil of dry rot in shipping. The importance of this, which is the first object of the invention. Every vessel hitherto that has perished by decay, at whatever age, has owed her decay to the same cause, which, in its swifter ravages, has of late obtained the name of dry rot. The comparative durability hitherto of timber in shipping, and in certain other situations. A second object, to be incidentally ensured by the invention, is the proper ventilation of the ship. The proper ventilation of a ship a thing not hitherto understood. The healthfulness of a vessel a question of money to the owner. A third and a great object is the preservation of goods from damage by heat. How, in general, such damage is caused. The invention does not interfere with

any of the established principles of ship building, nor affect any part of the ship on which its strength depends, except in one instance, which is to be compensated for by an additional thickness of timber. The application of the invention not expensive. The consideration of the room taken up, and the trouble of attendance. The room taken up does not exceed from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent. of the interior. The attendance of one man, in general, sufficient. The questions for a ship owner to put to himself, on considering whether to adopt the invention. Encouragement to an early putting of the invention in practice. Page 114

CHAPTER XI.

Explanation of the plates. Page 127

The specification of the author's invention under the letters patent. Page 137 to 169

An index. Page 171

CORRIGENDA.

Plates I. and II. In the sections in these plates, the chimnies, with the discharging valves for passing off air from the parts of the hold which are situated below the quarter-deck and forecastle, should have been represented to commence at the deck, and pass up through the quarter-deck and the forecastle, as in the profile.

Plate III. *7b.* This chimney-stave is shown too abruptly curved, so as to represent it too weak where the curved part begins.

THE

CAUSE OF DRY ROT.

CHAPTER I.

The cause of dry rot stated, with the circumstances of its discovery. The quick passage of heat through the timber is the cause. Introductory observations on the objects of the work. An underground vault of the author described. A large quantity of heat required to enter or leave it sensibly to alter its temperature. A new door put up in it. The changes of temperature of the vault with the changes of the seasons. The new door becomes dry rotten. Inquiries into the cause. Various possible causes considered and rejected. The true cause discovered.

When the premature decay of timber, commonly called the dry rot, takes place, it is, where the temperature of the air and other substances on one side of the timber is higher than at the opposite side, and where the timber is placed in such a situation as that a current or stream of heat, more or less rapid or considerable, issuing from the substances of higher temperature, is commonly working its way through the timber from the warmer to the

colder side, for penetrating and raising the temperature of the substances of lower temperature at the latter. It is the heat coming into immediate contact with every part of the interior of the timber in such its passage through it, and exerting an action of some sort on it, and on any wet that may happen to be contained within it, that, by degrees, when its action is sufficiently quick, and is continued in the whole sufficiently long, causes the decay. The mode in which, or the reason why, a current of heat so passing through timber causes the decay, it is not necessary for me, for my present purpose, nor do I intend to make it any part of my present undertaking, to establish; but only the fact that it does so. I shall, perhaps, hereafter venture to make a suggestion on this subject, but it will be matter of supererogation; and if my suggestion be not thought well founded, it will be of no consequence. But as to the fact, that the cause assigned is the true cause of the decay, I shall establish it to the satisfaction of every person.

Supposing, for the present, the cause assigned to be the true cause of the decay, the most obvious and natural remedy for the evil, if practicable, would appear to be, to guard against exposing timber to be so acted on, while still it is continued to be made use of for the same purposes, in general, as before. And in proportion to the extent to which this remedy can be carried, and its cheapness, will be the advantages of the remedy.

In bestowing my thoughts, in consequence of having discovered the cause of dry rot, how best to

prevent it, I have chiefly confined myself to devising the proper remedy for the evil in shipping; shipping being constantly, and more so than almost any thing else, exposed to the action of this cause of decay; and its preservation from dry rot being, from the expensive nature of a ship, and its liability to rapid destruction by the cause in question, an object of the greatest importance. And I shall show, that it is very practicable, at a trifling expense, compared with the object in view, to protect the timber of all shipping from being acted on by the assigned cause of the decay, if not entirely, at least to a very great extent; and so as, either entirely, or to a very great extent, to do away with the evil of the dry rot.

My first object, on making my discovery, was to devise the means of preserving timber from the dry rot; and I had put upon paper the first outline of the greater part of the contents of the following pages, before any other object presented itself to me. But it by and by occurred to me, the having heard of many kinds of goods being liable to be damaged or spoiled, on board ship, by heating or fermenting, during the voyage; and I saw that my remedy for the evil of the dry rot would, if it were extended also to the goods, have likewise the effect of preserving the latter from damage by heat. I thereupon added this to my former object; and the latter has appeared to me to rise in importance every time of its coming under my consideration; insomuch that I now look upon the preservation of the kinds of goods in question from damage by

heat, as an object of equal importance with that of the preservation of the ship itself from dry rot.

Before proceeding to state what I have to advance, to establish my foregoing propositions, it may be the most satisfactory course, as well for putting beyond dispute the fact that it was myself who made the discovery, as for affording some evidence of the discovery being that of the true cause of the decay, to give an account of the circumstances under which I made it, and of the kind of sifting and scrutinizing process of reasoning by which I arrived at it.

I entered on the occupation of my present dwelling house, which is in Chancery Lane, in January, 1821. Behind this house, under the Rolls Yard, I have two vaults, one situated beyond the other, that is, the entrance to the second, or farthermost from the house, is through the first, and the entrance to the first is by a door-way, immediately from the back area of the house. A brick wall, with a door-way and door of rather a small size, the door fitting close against its frame, forms the partition between the two vaults. Except where these two door-ways and doors are placed, both vaults are completely enclosed with, and composed of, brickwork; and they are covered with the earth and stones forming the Rolls Yard. The first vault is about 10½ feet long, 7½ wide, and 6 high, to the crown of the arch. The second is 18 feet long, 14 wide, and 7½ high, to the crown of the arch. The thickness of the party-wall between the two is about 14 inches. From these

dimensions, it will be seen, that the second is a very spacious vault, that its solid contents of brickwork form a large mass, and that its area, or the ground it encloses, is also spacious, and forms a large mass; insomuch that the brickwork and the earth or ground enclosed by it, must, with the changes of the seasons, alternately receive and give out a large quantity of heat, in order for the temperature within the vault to be raised or lowered any considerable number of degrees on the thermometer. The dampness of this vault at the time I took possession of the house was very great. Every part of the arch and walls was dripping with wet; and the ground was so soaked with water, as to sink under the step. The door and door-frame were at this time completely rotten; and I remember having been then told that a new door in that place always decayed in four or five years. I, however, caused a new door and door-frame to be put up. It was a deal door with an oaken frame.

From the excessive dampness of the vault, and not being a judge of the best kind of cellar for keeping wine in, and there being a small wine-cellar within the house, I was both afraid lest the wetness of the vault might injure any wine that might be put there, and thought the cellar within the house the most convenient. I consequently had the greater part of my wine laid down in the last named cellar, and only a few dozen bottles in the vault, and which last mentioned bottles I caused to be laid there, partly by way of experiment, to ascertain whether the vault injured

the wine, or whether it might not, on the other hand, be the better place for keeping it in. Having, however, by the end of 1823, consumed all the wine that had been laid down in this vault, I was induced, in the March following, to put more into it; and in April, 1825, I began to take a weekly account of the temperature of the vault with the highest temperature of my dining room in the course of the afternoon of the same days. And ever since October in that year, with the exception of a very few weeks, when the family have been out of town, and two or three instances of forgetfulness, I have taken, every week, an account, first, of the temperature of the vault; secondly, of the back parlour of the house, in the forenoon, without a fire; and thirdly, the highest temperature of my dining room after dinner, noticing when fires were commenced, or left off. These temperatures have always been accurately taken. During all this time, too, till the time of making my discovery, I was in the habit of taking notice, as well as I could by help of the light of a candle, of the changes in the dryness and moisture of different parts of the vault, with the changes of the seasons and the weather.

The result with respect to the temperature, as shown by the thermometer, is, that when the vault door is kept shut, the difference between the temperature within and that of the outer air in the hottest days of summer, is about 20°; the temperature of the vault then being about 20° lower than that of the air. By having occasionally put my

thermometer out at the window when there has been a severe frost, I have also found that there is just about the same difference in the coldest weather of winter, the vault then being about 20° warmer than the outer air. I mention these as the greatest differences, or the differences of the hottest and the coldest days only, the general difference being considerably less. Thus, I find, I have these entries of temperatures of the vault and my front room on the following days:

		Thermometer.		Thermometer.
1825.	July 3	Vault, 58¼		Room, 72
	10	59		72
	17	62		81
	[Tuesday 19	(No account.)	First Floor Back Room,	85]
	24	64		70
	31	63		76
	August 7	62		73

In the October following I began, as I have said, to take a weekly account of the temperature of the back parlour without a fire, in addition to the temperatures of the vault, and of the front room on the first floor, the latter with or without a fire, according to the season. I shall insert a considerable number of the results of these observations, as showing the actual temperature of the vault at the different periods, and as also, although not exactly showing what difference there was between its temperature and that of the outer air, whether in the summer or in the winter, yet affording the means of judging nearly about what must have been the difference.

1825.	Thermometer.	Thermometer.	Thermometer.
Oct. 16	Vault, 58	Back Parlour, 62	First Floor Front Room, 72
23	55½	(No account.)	(Fire in the Room.) 67
30	54	64	70
Nov. 6	55½	(No account.)	64
13	51	47	64
20	49	51	68
27	49	53	69
Dec. 4	49	51	70
11	49	54	(No account.)
18	49	57	71
25	49	55	70
1826.			
Jan. 1	46	51	68
8	45	45	67
15	42½	41	65
22	41	50	68
29	41	52	68
Feb. 5	44	53	68
12	44	51	68
19	45	54	68
26	46	53	70
Mar. 5	47	55	70
12	48	55	70
19	47	50	64
26	46	46	65
April 2	45	54	70
9	48	64	74
16	49	61	69
23	50	58	68
30	49	53	66
May 7	49	54	67

1826.	Thermometer.	Thermometer.	Thermometer.
May 14	Vault, 50	Back Parlour, 57	First Floor Front Room, 68
21	52	62	(Fires left off.) 72
28	54	64	68
June 4	54	64	69
11	56	68	75
18	59	73	77
25	60	71	76
July 2	63	74	(No account.)
9	64	76	76
16	64	68	72
23	62	65	68
30	62	72	77
Aug. 6	63	69	72
13	63	68	70
21	63	73	78

At this time I took my family out of town for a few weeks. In the preceding January, while the temperature of the vault was 41, I, on two occasions, put the thermometer out at the window; and on one of the occasions it fell to 20, and on the other to 18, being the lowest point at which I have ever seen it, and this being at 11 o'clock at night, and at the outside of the staircase window, with an east or a north east wind.

Having been in the practice of taking these observations, and also in the habit of bestowing some thoughts on the progress to maturity of a little stock of wine which I was forming, and having completed a set of bins round the vault, which at first contained only three; but what I had been told respecting the door of this vault always getting

rotten in four or five years, never having once recurred to me; in October 1826, while locking my new, and, as I supposed, still sound door, on coming out of the vault, I fancied I perceived that the door, in one part of it, had a little given way, or was a little warped, or shrunk inwards. I instantly applied my thumb nail to the part, and was exceedingly surprised to find that it penetrated the wood as easily as if it had been the cut part of a cheese. What can this be, thought I? how can it have happened? the door has met with no rough usage; and it was new four or five years ago. I tried with my nail again on another part: it was equally soft. Surely it must be what we hear so much of, as making such havoc in the navy; it must be the dry rot! How dry it looks! It cannot be the wet that has done it. Why, it looks as dry as kecks! These thoughts passed through my mind, and I began to feel a strong desire to find out what it was that had caused the decay.

The next week, although, from not being able to account for the decay, and from never having till now bestowed any thoughts on the subject of dry rot, the evidence of my own eyesight and touch could scarcely satisfy me that the door was really so decayed as it seemed to be; or, at first, nor till I had closely examined it on both sides, that the decay could have penetrated any considerable way in, I nevertheless again began to turn the subject in my mind, somewhat as follows. It cannot, as I said before, be the wet, because the wet has never touched the decayed part. The paint on the door has kept the wet even from touching any part of

the timber itself; till now, that, from having become so completely rotten as not to be able any longer to retain its own shape and original form, it has shrunk and cracked; and even now the wet does not appear to have entered the crack, and reached the rotten part. If it were the wet, must it not have decayed the outside first, just as it rusts iron, while the interior remains sound? But here the outside is the soundest part, and it showed no symptom of decay till after the interior had become completely rotten, so completely so, as for the surface to have shrunk inwards from the loss of substance in the interior, and for want of internal support, or, perhaps, from the same cause, to have been pressed inwards by the weight of the atmosphere. Then, can it be the air that has done it? There are the same answers to this supposition as to the former, namely, that the paint has kept the air from coming into any actual contact with the timber, and that it is the interior of the timber that has first become rotten. It cannot be the want of air, because there always has been the air in contact with it, as much as it can be in contact with timber painted; and, if it were this, all painted timber must become dry rotten, which is not found to be the case. Can it be the want of a circulation of the air? I should think not. I cannot understand how the want of the air being in continual motion, or being commonly in motion, against the outside of timber can rot it in the interior, without first decaying the outside. Is it foul air? The same answer applies, that, if so, we should naturally expect it to decay

the outside first; to decay that which it touched, and not that which it did not touch. Besides, there is no foul air here, that I can perceive. The servants' water-closet, indeed, is just within the outer vault, and sometimes, when the water-cock is neglected to be turned, the common smell of a privy is very perceptible. But the water-closet is close to the outer door, which is not dry rotten, whilst it is nine or ten feet distant from the inner door, which is so. Besides which, I never heard that the dry rot was particularly prevalent in places of this description.

Again, it can neither be the light nor the darkness of the place that has caused the rot. For, with respect to the first, the door, even when the outer door of the outer vault is open, is never in the full light of day. And, with respect to the darkness being supposed to have caused it, the interior of all timber is always in the dark; and, moreover, if this were the case, all timber must be dry rotting during the night, and the inner sides of all dark closets, cupboards, and drawers, both night and day.

It cannot be the cold of the place where the door is fixed that has caused the rot; because it is never so cold there as it often is at the outside of the outer door, and of all our outer doors. On the other hand, it cannot be the heat of the place, because it is never so hot there as in summer it is in the open air, to which all our outer doors and windows are exposed. It cannot then be caused by the door, or other timber, being placed in a high temperature, or by its being placed in a low temperature. What, then, thought I, can heat have

nothing to do with it? Can it be caused neither by heat, nor by cold, nor by changing from heat to cold? Stop! That does not follow. But, how? How is this door affected by the changes in the temperature? I have it! I have found it out! It is the heat which is so constantly working its way, in such a quantity, through the timber of the door, in the one direction or the other, and which, now that some frost is come, is working its way out, and leaving behind it all that wet which it has deposited against the inner side of the door within the vault, and which is now running down so plentifully, and making a little pool of water in the ground, that has caused the decay. It is this heat, so almost continually forcing its way through the door into and out of the vault by turns, and, in so doing, coming into immediate contact with, and exerting an action of some sort on the whole of the interior of the timber, that has by degrees effected its decomposition as timber, and made it so rotten as it is. It was by turning the subject in my mind, and sifting and scrutinizing it in this manner that I came to make my discovery of the cause of the decay.

CHAPTER II.

Arguments that the assigned cause of dry rot is the true cause. A large quantity of heat passed through the vault door while it was dry rotting. The proof of this, on various grounds. The property of heat to pass through substances towards equalizing temperatures. The quantity that passes does not depend on the absolute height of the temperature, but on the difference of the temperatures on the opposite sides of the substance passed through, and on the nature of the substance, and other considerations. Argument that a large quantity of heat passed through the door, from a very large quantity having alternately entered and left the vault. A further argument, from the slowness with which heat can pass downwards through a body of air, and from the thinness of the door compared with the thickness of the brickwork. Two circumstances conclusive as to the fact: first, the depositing of water against the outside of the door on the approach of warm weather, by the heat, which kept it suspended in the air, leaving the air in order to pass through the door; secondly, the converse of the first, in the depositing of water against the inner side of the door on the coming of cold weather. Why the water is so deposited, and in such large quantities, as alleged. An occasion on which much heat was caused to pass out through the crown of the arch, attended with the like depositing of water. The vault door set open on the first frost of an autumn, and a strong current of air into the vault at the lower part, and out of it at the upper part of the door-way immediately taking place. The cause of the current. A further instance of the depositing of water, on heat leaving the air to pass through a colder substance. A circulation of air is constantly going on in a close shut vault, while heat is entering or leaving it. Water taken up from the inner side of the vault door on the entering of heat is quickly deposited again on the colder bottles of wine in the vault, and on the highest bottles first.

I HAVE stated that that which causes the decay of timber, commonly called the dry rot, is a current

or stream of heat, more or less rapid or considerable, working its way, in one direction or another, through the substance of the timber, and, in so doing, coming into immediate contact with, and exerting an action of some sort on, every part of it through which it works. And I may properly here apprise the reader, that it will be incumbent on me to show that the quantity of heat required to work its way through the timber, in order to produce the decay, must, in the whole, be considerable, to enable me hereafter to establish the practicability and certainty of the remedy.

I shall first proceed to establish the fact, that not merely what may be deemed a considerable quantity, but a very large quantity, of heat, in the whole, must have passed through, and a considerable current or stream been commonly passing through, my dry rotten vault door, whilst the decay was taking place. And among the matters which will be advanced under this branch of my subject, some, the immediate application of which may not be so obvious, will be useful in clearing the way for a more ready reception of the remedy to be afterwards stated.

The knowledge as yet acquired of the nature of heat, and the laws by which it is governed, is, I believe, still very imperfect, and very inadequate to account for many of the phenomena of nature, which are nevertheless intimately connected with the operations of heat. Many erroneous notions respecting it, I know, have heretofore prevailed, and some, I believe, still prevail. But it will not

be necessary for me, for my present purpose, to advance any novel or questionable positions regarding the nature of heat, but only such as will not be disputed, and of these only a few.

In the first place, then, heat, in its active form, in the form in which it governs the temperature of substances as indicated by the thermometer, has a constant tendency to leave substances of a higher temperature to penetrate those of a lower temperature, in contact with or situated near them, for raising the temperature of the latter towards an equilibrium with the now reduced temperature of the former. If the newly penetrated substance has another substance, in contact with it, on its farther side, of a still lower temperature, whether the latter be atmospheric air or a body in a solid form, the heat, instead of remaining in the newly penetrated substance, will leave it to penetrate the latter, in the same manner, and for the same purpose, as in the first case. And, if either of the two first mentioned substances be, from any cause, now become of a lower temperature than the substance last mentioned, a portion of the heat will begin to go back again into one or other of the former.

The quantity of heat which, where only a change of temperature, without the decomposition of any substance, is taking place, leaves a given substance to penetrate and for a time remain in, or to penetrate and immediately pass through, another substance into a third, does not depend upon the temperature being positively high, as indicated by

the thermometer in common use, but, ceteris paribus, upon the difference in the temperatures of the different substances. If the temperature of different substances be the same, the heat in them will, for so long, be at rest. But if there be a difference of a certain number of degrees in the temperatures of two different substances placed on the opposite sides of a third, and the heat cannot pass from the hottest of the two former to the coldest, without making its way through the third substance, as, for example, the bodies or volumes of common air on the outside and inside of a closely shut up vault, through the walls or door of which the heat must make its way, to pass from the one body of air to the other, it will work its way through the walls, or door, or both, from the hottest to the coldest side accordingly; provided the difference of temperatures, according to the degree of resistance which the substance to be passed through will present to the passage of the heat through it, be sufficiently great for the heat to overcome such resistance. For it is to be observed, that most (perhaps all) substances in a solid form, present some resistance to the passage of heat through them; and those which present the greatest have commonly been called slow or bad conductors of heat. Among these are the different substances which we make use of for wearing apparel (more especially woollens,) and so also is timber, and the latter more especially so, when it is very solid and free from wet in its interior. And that these substances do present some resistance to the passage of heat through them is

clear; for, to instance timber, if it were otherwise, there would be no sensible difference between the temperature of the air just at the outside of the door of a room having a fire in it, and of the air just at the inside of the door within the room; which is contradicted by experience.

If, however, the difference of temperatures on the opposite sides of a given substance be so great, as that more or less heat, heat moving with a greater or smaller velocity, is working its way through it, I know of no reason why as large an actual quantity of heat, where no decomposition or change in the organization of the substance is taking place, may not pass through it with the same difference in the temperatures on the opposite sides, in low temperatures, as indicated by the thermometer, as in higher temperatures; why, for instance, as much heat may not pass through, when the temperature on one side is 50° and on the other side 30°, as when it is on one side 70° and on the other 50°, or when on one side it is 5° and on the other side 15° below 0°, as when it is on one side 50° and on the other 30°. It is, indeed, from what I have lately observed of heat, quite certain, that in particular circumstances, as, for example, if there be more moisture in the air, or if there be wet either in the interior, or in contact only with the outside of the substance to be passed through, even a larger quantity of heat may, with the same difference of temperatures on the opposite sides of the substance, work its way through it in a lower temperature than in a higher temperature, where no such circum-

stances exist. And at all events it would be for any person who was disposed to assert that only a small quantity of heat can pass through a given substance with the same difference of temperatures on the opposite sides of it at low temperatures of the thermometer, compared with what passes through at higher temperatures, to give some evidence of facts in proof of his assertion; and, in order to make it bear on the present case, to prove that but little heat passed through my vault door, whilst its decay was taking place.

The quantity of heat that will work its way in a stated time through a given substance, besides depending upon the difference of the temperatures on the opposite sides of the substance to be passed through, depends also, among other circumstances, on the power of resistance of the particular substance to the passage of heat through it. And the length of time a current of heat will on any occasion continue to work through any substance, and, consequently, the quantity that will pass through in the whole, depends both on the quantity or supply of heat that there is on the hotter side, to pass through to raise the temperature of the colder substances on the opposite side, and on the quantity of those substances, and the quantity of heat, which according to their several natures, they will take, to have their temperature raised to the point of approximation to that on the other side of the substance passed through, at which the resistance of the latter will prevent the further passage of heat through it.

If these propositions be not wholly false, a large

quantity of heat must have been passing through my vault door, inwards on a change of weather from cold to warm, and outwards on a change from warm to cold, and, in the whole, a very large quantity must have worked its way through it, during the time of its decaying. For the observations with the thermometer before given, although they do not include observations of the actual temperature of the outer air, afford the means of judging pretty satisfactorily of nearly about what must have been the difference between it and the temperature of the vault, both in summer and winter; and they show an actual range of 23° in the temperature of the vault itself. Then, considering what must be the solid contents of so spacious a vault itself, and, still more so, of the solid ground forming its area down to as great a depth as can be reached by any changes of temperature between summer and winter, and the quantity of heat that so large a mass of substances must, in changing its temperature any considerable number of degrees, alternately receive and give out, it is clear that, even supposing a small proportion only of the whole to have passed through the door, still, comparing the size of the door with the size of the vault and the total quantity of the heat, the quantity that, even in any reasonable supposition of this sort, must have passed through the door, must have been such as, regard being had to the general nature of my proposition, ought to be described as a large quantity.

But I have other reasons to assign, and circum-

stances to state, which are quite conclusive as to the fact of a large quantity of heat having passed through the door during the period of its decay taking place. With respect to reasons, it is clear, that, from air with any given quantity of heat in it being ceteris paribus specifically lighter than colder air, heat can comparatively very slowly propagate itself, or make its way downwards through a body of air which is shut up or inclosed in any place, so as that it cannot be changed. For instance, heat in summer time passes very slowly, if at all, down through the body of air contained in a well, to raise the temperature of the water at the bottom. But comparatively little heat, consequently, can, at the approach of hot weather have made its way, after passing through the crown of the arch of my vault, down through the air within it, to penetrate and raise the temperature of the ground below, or of the lower parts of the brickwork itself, or the stock of wine the vault contained. By far the greater part of the heat, which entered on the approach of hot weather, must, therefore, have entered by passing through the side walls, or the door. But although timber may possibly, (for I cannot state how the fact is,) present a greater obstruction to the passage of heat through it than brickwork, if of the same thickness, yet, in the present case, from the door, which was only an inch thick, being so much thinner than the brickwork, which was about fourteen inches thick, it is reasonable to conclude, that a larger portion of heat passed through the door, than through any part of the brickwork of

the same superficial dimensions. But, besides these reasons for considering that a large quantity of heat must have passed through the door, there are two other circumstances that I will now mention, which are conclusive as to the fact of its having done so. These are, first, that at the coming of warm weather on the breaking up of winter, and even in the depth of winter on a sudden change from a frost to a warm south west wind, the outer side of the door becomes wet, till at length the water trickles down it, and soaks into the ground; and the inner side of the door, which is, at first, extremely wet, begins at the same time to get dry; and, if the additional warmth of the weather continues, soon becomes quite dry. The second circumstance is the converse of the first; namely, that, on the approach of the cold weather of the autumn, and more especially as soon as a sharp frost comes, the inner side of the door becomes so wet that the water presently runs down it so fast as even to make a little pool of water in the ground, and the outer side, at the same time, if it happens to be wet, (for the wet originally deposited at the approach of warm weather will long ago have been dried up, but yet other wet may have been recently deposited against it,) becomes quite dry. Now all the water, in both these cases, is produced by the precipitating or collapsing into the form of water, of a quantity of the component parts of that body which is held suspended in the air at the time of its coming into contact with the door by the heat that there leaves it to pass through the wood; and which, not being

able to pass with the heat, is, on the latter leaving the air in immediate contact with the door to work its way through it, precipitated and deposited in the form of water against the door itself; where, as the water increases in quantity, it trickles down, and runs into the ground. And when the opposite side of the door, out at which the heat issues, is wet, the heat, in passing out, takes the water up with it into the air, and in so doing dries that side of the door.

But, as I have spoken of so large a quantity of water having been left deposited against the door, and more especially against the inner side of it when the heat has been working its way out; and it may be truly objected that all the moisture that could be contained at any one time in the whole body of air within the vault, if converted at once into water, could not make near so large a quantity as I have been describing, it may be proper to give some explanation of the process which is going on by which so large a quantity is produced. Heat, then, issuing from a substance more or less saturated with water, and out of which the water itself can also pass, into a body of air of a lower temperature, (and unless the air be of a lower temperature the heat will not pass into it,) takes up and converts a part of the water into some sort of gaseous state or form, and carries it along with it into, and holds it suspended in, the air. But if we suppose the body of air, as in our case, to be shut up within a vault, and that the heat rises out of the wet and warmer ground into it, the operation must

soon cease, by the temperature of the air being raised so as to be equal to that of the ground, provided the temperature of the external air be equally high, so as that none of the heat passes out of the vault. If, however, the external air be colder, and a part of the heat within the vault, in consequence, makes its way out, (for instance, through the door,) a circulation of the air within will take place, notwithstanding the vault may be kept close shut. The air within the vault in immediate contact with the door, will, as to so much of it as consisted of the ingredients of water kept suspended in a gaseous form by the heat which has just left it, be collapsed into water. There will thus be created a partial vacuum at the door, which will cause the air farther in to approach and come into contact with it, and in its turn to part with a portion of its heat. And each complement of air becoming, by the loss of a portion of its heat, specifically heavier, will fall to the ground, and flow back to the farther end of the vault, receiving in its way a new supply of heat and moisture, from the wet and warmer ground and brickwork and other things contained within the vault, and thereupon rising and again coming into contact with the door, and again parting with some of its heat; and so, toties quoties, as long as the external air continues colder, and any heat makes its way out. In this manner, it will be seen, a much greater quantity of water may be deposited against the door than could be kept suspended at any one time in the whole body of air contained within the vault.

I have still two other occurrences to mention with regard to the vault in question, which go to confirm what I have been stating. But I should here remark, that (as will be shown by the first of these occurrences), it is not to be understood, that all, or nearly all, the heat, which passes out of this vault in cold weather, passes out through the door. For the crown of this arch being considerably loftier and nearer to the surface of the ground than that of the first or outer vault, although still at the depth of full two feet below the surface, a sensible quantity of heat passes out through it, and, on the occasion I am about to mention, a considerable quantity undoubtedly so passed out. This arch being so lofty, some four or five years ago, and before I began to concern myself with the temperature of the vault, I wished to try the experiment of improving some old Somersetshire cheese by making it mouldy. For this purpose, I caused a shelf, about twelve feet long, to be suspended, by means of iron frame work, from the crown of the arch. It was in the autumn, and seeing that the under side of the arch was wet, with the view to protect the cheese from water dropping on it, I caused two boards matched and beaded together so as to be water-tight, and being, together, both wider and longer than the shelf itself, to be fixed close to the crown of the arch immediately over the shelf, so as that they might shoot the water, which, I supposed, penetrated through the brickwork from the yard over head, to a sufficient distance all round, to make it clear the shelf in falling to the ground.

These boards, I may remark, were planed quite smooth, but they were not painted. Having put one half of a cheese on the shelf, by way of experiment, I went to the vault at the end of about twenty days to see what progress the cheese had made in getting mouldy. With a good deal of surprise, I saw, that, notwithstanding my precaution, it had become completely soaked with wet, and that a rank, bad-smelling mould, not less than half an inch long, had already grown out of it, at the part where it had been cut. On looking up, I saw that the whole of the surface of the board covering above, had large drops of water hanging from it, some of which dropped on the shelf every minute. The cheese had acquired a bad taste; and the experiment having, therefore, failed, I sent to the carpenter to remove the shelf. I had still taken it for granted, that the wet had penetrated from the yard above through the arch; though I could not account for its having so soon soaked through the board covering. But, lo! on the covering being taken down, it appeared that the whole of the wet was on its underside, and that the side which had been the uppermost, and been in immediate contact with the brickwork of the crown of the arch, was quite dry. It was plain, therefore, that none of the water had come through the arch, but that the whole of it must have risen from the lower parts of the vault; but, I believe, it did not at that time occur to me, that it had been left there by the heat leaving the warmer air of the vault in contact with the board covering, and passing out,

through the covering, and the brickwork over it, into the open air.

The other occurrence, connected with the vault, which I have to mention as showing a circulation of the air to have in fact gone on within it, is the following. A few bottles of wine, which I had bought, in the early part of 1826, seven or eight years old in bottle, and with the corks already partly decayed, having been laid in some old rotten sawdust, a mould, which on the wine being decanted gave it a mushroomy taste and spoiled its flavour, had, by the latter end of the summer, grown out of the corks close to, and in contact with, the edge of the neck of the bottle. To guard against the like happening in future to other wine, I, in the latter end of the following October, on the first frost, with the view to make the vault both colder and drier than it ever had been, set the doors of both vaults wide open, and I kept them open all night. Having so set the doors wide open, I was standing with a lighted candle in my hand, in the middle of the large vault, when, presently, I thought I felt a regular current of air passing by me, and more especially against my legs. There was no wind blowing; and if there had been any, it could scarcely have disturbed the air so far within the vaults, as where I was standing. Recollecting that, if we open the door of a room with a fire burning in it, and hold a candle in the door-way near the floor, a current of air will drive the flame inwards, and if we hold it in the upper part of the door-way, a contrary current will drive it outwards,

I tried whether it would be so in the door-way of the large vault, and I immediately found that there was a regular, and even a strong, current of air entering at the bottom of the door-way, and passing on along the ground to the farther end of the vault, and, as it grew warmer, rising upwards, and passing out, in as regular a current, at the upper part of the door-way. The temperature of the vault at the time of setting the doors open was 54°, so that, in the night, at least, when it was freezing, the difference between the temperature within, and that of the external air, must have been full 22°. It is evident, that this difference of temperatures causes the current of air, the specifically heavier cold air entering, and moving along at the bottom and receiving in its passage the heat rising from the warmer ground, and also the wet (taken up and changed by the heat into a gaseous state or form,) and when warmed being pushed up to the top of the vault, and forced out, by a continued succession of colder air entering at the bottom; and that thus a constant circulation of air is kept up throughout the vault, so long as it continues of a higher temperature than the outer air. And the strength of the current of air, will, ceteris paribus, be in proportion to the difference of the temperatures.

In the course of the winter I set the doors open, on two or three other occasions during frost, and kept them open, in the whole, about eight or nine days, day and night. The vault was by these means made much drier than it ever had been, and it was cooled down to 34°, being only

2° above the freezing point, and being 7° lower than it had fallen to in the coldest weather of the preceding winter, when the doors were kept shut. During the time of the doors being kept open, the heat must, therefore, have carried out with it a very large quantity of water; as was, indeed, evidenced in still another way, namely, by the cross timber of the top of the outer door-frame, in contact with which the warmer air passed out, having been all the time covered with large drops of water, which the heat that in its way out entered and passed through this colder timber into the still colder brickwork which rested on it, left deposited against it. But, with respect to my position, which what I have last been stating was to corroborate, namely, that a circulation of air goes on within the vault, when the external air is so much colder as that a part of the heat is passing out, notwithstanding the vault may be kept shut, the consequence of shutting the door is only to shut in the air and wet, and to prevent the heat from passing out so fast as it otherwise would. But supposing any heat to pass out through the door, or any other part, the air within the vault, in partly collapsing into water, and, as to the remaining part, becoming specifically heavier from the loss of heat, and in consequence, falling to the ground, causes, as I have already said, a partial vacuum; and thus, it cannot but cause a circulation of air to take place within; although it will be a weaker circulation, in proportion to the hindrance the heat meets with in working its way out. A

like circulation of air must take place, when heat is making its way into the vault, with this difference, that, supposing the doors to be set open, the direction of the hot air, which will still be at the top, will be inwards, and that of the cold air, which will still be at the bottom, will be outwards. The hot air will enter inwards in consequence of the colder air leaving a partial vacuum on flowing out, which it will by its greater specific gravity; and when the hotter air is in, the heat will begin to leave it to penetrate the colder substances of the vault and its contents, with the ground within; and thus, it will, in its turn, be cooled; and if more heat leaves it than, with the actual proportions of its other component parts, it can part with without some of the moisture contained in it being precipitated in the form of water, a part will be precipitated accordingly; and the remainder of the air being now so cooled, will roll out of the vault by its greater specific gravity.

When the door is kept shut, and heat is penetrating through it inwards, and taking up with it any wet that is deposited against the door on the inside, the wet is soon seen again, deposited on the bottles of wine; and, at first, only on those bottles which happen to be placed the highest, and in contact with which the newly heated air, from its being specifically lighter, first comes, and immediately whereupon, a part of the heat leaves it, to penetrate through the glass of the bottles into the as yet colder wine contained in them. And this depositing of wet on the bottles will take place even with an inconsiderable increase of the temperature of

the vault, the reason of which is, that, when the door is kept shut, the same air is shut up in the vault, and, as any accession of heat to it issues from, or comes through, substances either more or less saturated with wet, or, at least, having wet lodged against their surface, the heat, in taking up such wet, quickly supplies to the air as much moisture as, with its other component parts, it can contain, and hold suspended, in its actual temperature; and, consequently, the instant a part of the heat again leaves it, a part of such moisture is again precipitated, in the form of water, against that substance with which the air is in contact, when parted with by the heat. And this proceeds in my vault with such exact regularity, the water being deposited on the highest tiers of bottles first, on the middle tiers next, and on the bottom tiers last, while in the meantime the upper ones have perhaps again become dry from a part of the heat having again left those bottles, as to make it a thing really curious to witness.

Many of the statements which have been made going to show that the vault can very seldom be of the same temperature in every part, I have here to notice that, on taking the observations with the thermometer, I always placed the instrument on the same spot, and that this was between three and four feet from the ground, on the top of a decayed piece of timber, covering a brick partition between wine bins, the partition being one brick thick, and the piece of timber about three inches deep by four wide, and about three feet long.

CHAPTER III.

Further arguments that the cause assigned is the true cause of dry rot. None of the other supposed causes before mentioned the real cause. Another possible cause supposed and rejected. Cases of what is sometimes called wet rot instanced, with a conjecture as to its cause. The necessity, in general, of a current of heat through the timber, to cause dry rot. A possible objection to the assigned cause of dry rot anticipated and answered. Various instances of the effects of the quick entrance or passing off of heat into and from different kinds of substances. Conjecture as to how the cause assigned works the decay. Fungus, or insects, not the cause, nor always present. Fungus when present may hasten the progress of the decay, and how.

It is now fully established, that a current or stream of heat, more or less considerable, must commonly have been passing through my vault door during the time of its decay taking place, and that during that period, a large quantity, in the whole, must have passed through it. And I take it to be quite unnecessary to give any other answers than those already given, to the supposition of any of the other causes before mentioned, which presented themselves to be considered while I was examining into the subject, being either jointly or separately the true cause of the decay. On looking over what I have there written, I see, indeed, that although I stated, and answered, the suppositions of its being either wetness or dryness of the timber that caused

the decay, I did not directly consider whether changing from wet to dry, and dry to wet, could be the cause. But there is the same answer to this that there was to several of the other supposed causes, namely, that, the door having been a painted door, no part of the timber itself was, in fact, touched by the wet, till the decay in the interior was completed, and the surface of the door had shrunk inwards, and the paint become cracked. And in what has since been stated, it appears that, where timber is placed in such circumstances as that it sometimes becomes wet and dries again, without being exposed to rain, or otherwise having water immediately brought into contact with it, the changing from dry to wet, and from wet again to dry, is itself only a consequence, and but an accidental consequence, of the temperature changing from higher to lower, and from lower again to higher; namely, a consequence as respects the timber's becoming wet, depending on the air on the warmer side being charged with more moisture than it can continue to keep suspended in it after being parted with by the heat which leaves it to pass through the timber, and, as respects its becoming dry, depending on an opposite change of temperature taking place, and, commonly, on the heat thereupon returning in the opposite direction through the timber, and, as it issues from it, taking up the wet along with it into the air.

Even in cases of what, I believe, is sometimes called the wet rot in timber, and in which cases the timber is penetrated by water, and where, perhaps, it is always more or less exposed to changes from dry to

wet and wet to dry, or from drier to wetter and wetter to drier, but where it is so placed as not to be necessarily exposed to have any current or flood of heat passing directly through it, I am strongly disposed to think, and, indeed, on considering the subject since the idea first struck me, I entertain no doubt, that it is the action of heat that, in these cases also, causes the decay. The most frequent instances of the kind of decay I am alluding to are found in gate-posts, and the upright timbers of cow-houses, and any timber let into the ground and more or less exposed to the weather. In these cases the decay always takes place first in that part which is just at the surface of the ground, and which, after rain, continues wet longer than the upper parts, and where the wet, consequently, penetrates deeper into the timber, while, at the same time, it is exposed to all the changes of temperature of the air, from day to night, and night to day, and season to season; to which changes the parts deeper in the ground are less exposed; and which last mentioned parts are always found less decayed than the former. Now, in these cases, in consequence of the powerful tendency of heat to penetrate water of in the least degree a lower temperature, and, where the water is not contained in a closed vessel, to unite with and take it up into the air in a gaseous form, the water, by having penetrated the timber to a certain depth, enables heat with facility, and perhaps almost instantaneously, to penetrate it to the same depth, and thereupon to exert within the timber, however ineffectually,

its action towards taking up the water into a gaseous form. And in so doing it would seem that it must exert some mechanical force on the substance of the timber itself, while, on a change of temperature, it will again leave it with the like quickness, and by the same way by which it entered, without there being necessarily any current, stream, or tide of heat passing directly through the timber, or, for a considerable while, even reaching to any considerable depth within it. And this serves to account for the decay in such cases commencing, as it does, at the surface, and proceeding by comparatively slow degrees to the more central parts.

It happens that, in my wine-vault, of which, and its door, so much has been already stated, there are three pieces of timber which are very much decayed by this last mentioned kind or species of decay. One of these I have just above incidentally mentioned, as being the place on which I put my thermometer, when ascertaining the temperature of the vault. The other two pieces are similarly placed, that is, as coverings of the brick partitions of two wine bins. Now all these pieces of timber have clearly been decayed progressively from the outsides inwards. How long they have been decaying, I know not. It must, however, have been a considerable number of years; for I see very little difference between their present state, and the state they were in seven years ago. They may possibly have been in the same place ever since the building of the house, which is, perhaps, a hundred years old, there being the date of 1730

on the leaden water cistern in the kitchen. The outsides of all these pieces of timber are completely decayed, and, in many parts, quite gone, and holes have been eaten (if I may use the word) inwards, from the ends of one or two of them, to the depth of two or three inches. That which remains of the most decayed parts is a very light or porous substance, that looks as if it would serve for garden mould, and there are now subsisting on it, and burrowing in it, several worm-like insects, and, I believe, worms themselves. The dimensions of these pieces of timber are, as I have said, about three feet long, by about three inches deep and four across, except that one of them, in consequence of the brickwork for a certain distance from the wall of the vault being about double the thickness of the remaining part, is about twice as wide across, as to that part of its length. These pieces of timber are in so great a state of decay, that I question whether, if they were to be sawed asunder, any part of the very centres would be found sound: but I have no doubt that the centres would appear sufficiently less decayed than the more outward parts, to make it apparent that the progress of the decay had been from the surfaces inwards. Now, from the situation in which these pieces of timber are placed within the vault, that is, with one end only touching either of the walls, and about midway from the ground and the crown of the arch, it is evident, that they have not been placed so as for any current or stream of heat to be necessarily working its way through them, in any of the

changes of the temperature of the vault. The temperature where they are, and, consequently, their own temperature, has, of course, been raised and lowered with that of the vault generally; and my observations with the thermometer, before given, show that the difference has been at least 23 degrees between summer and winter. And the circumstance of these pieces of timber having been always more or less wet from the droppings from the arch above, and from the door having been always kept shut, must from the first have enabled heat to penetrate the more quickly to the depth to which the wet penetrated, and to leave the timber again the more quickly on a lowering of the temperature. And, as I have said, I entertain no doubt that it has been the heat, so alternately penetrating and leaving the timber, that, by its action on it, and on the wet within it, has caused the decay. I shall, hereafter, shortly advert to the circumstance of there being insects in this decayed timber, and show that they have not been the cause of the decay, when I come to do the like with another thing, which, I find, has very generally been imagined to be the cause of dry rot.

The next point in my assigned cause of the decay of timber by dry rot, to which it seems proper to direct the reader's attention, is, that, as a general rule, it is only a current or stream of heat entering the timber on one side and passing through and out of it at another, for going on to raise the temperature of the air, or other substances, beyond it, on the side, out at which the heat issues, that is suf-

ficient to cause the premature decay in question; and that any common raising and lowering of the temperature in which the timber is, and, consequently, of the timber itself, is not sufficient to produce the dry rot. This point may be soon disposed of. One evening, during a sharp frost, in February, 1827, while employing myself on the present subject, having a very bright and fierce fire in my parlour, after having been taking some observations of the temperature in different parts of the room, I laid my thermometer on the chimney-piece, which was a deal board, at the height of only about two feet four inches above the upper bar of the grate. I placed it so as for the bulb, with the quicksilver, to project a little beyond the chimney-piece, and the thermometer rose to 94. In the same weather, in the morning, before lighting the fire, this chimney-piece was, every morning, in a temperature of not more than 44 or 45; so that it was exposed in the twenty four hours to a range of temperature of nearly, or quite, 50 degrees; and yet it has no mark of dry rot, or other decay. But it is so placed, as that the heated air from the fire can freely pass it, without the heat being under the necessity of working its way in a tide or current through its substance.

In advancing the general proposition, however, that it is only a current of heat passing through the timber that is sufficient to produce the dry rot, I am to be understood as only advancing a general proposition, and not a universal one, that in no other way can heat be applied to timber so as to decay

it by the same kind of action, and to produce the same kind of decomposition, whatever the mode of action may be. Thus, it is easy to conceive that, by the direct action of a burning sun on a black or dark-coloured metallic painted surface of timber, such a quantity of heat may penetrate the timber to a certain depth, without going on to pass through it, as by degrees to decompose the timber to the depth to which it reaches. And this may happen to a black painted bulwark of a vessel, round which the air can freely circulate, so as that no current of heat will be passing directly through it, to raise the temperature of any substance on the opposite side to that at which the heat enters. And I have accordingly been told that the sun, in hot climates, does sometimes decay timber forming the bulwarks of a vessel to a certain depth within it, while the inmost parts remain sound, but which, I apprehend, is seldom or never the case, where the current of heat goes quite through the timber.

As it is heat forcing its way through the substance of timber, that causes the decay, so it is necessary that the passage of the heat be continued, in the whole, a considerable length of time. Besides that all experience shows, that it requires some time to effect the decay of timber by dry rot, although with some kinds of timber, and in some situations, it is, doubtless, effected much more expeditiously than with other kinds and in other situations, it would not be reasonable to expect that so common, and every where present,

an agent, as heat, of no higher a temperature or degree of concentration than what is found in the common air of the atmosphere, should decompose, at a single stroke as it were, like a flash of lightning, that which, in the process of vegetation, it certainly assisted, and took a long while in assisting, to compose. But I shall defer insisting on its requiring time to effect the decay, till I have anticipated and answered a few adverse notions, that may possibly be set up as objections to one part or another of what I have been advancing.

First, then, it may be thought that, supposing the passage of heat through timber to be the cause of the decay, yet it is unreasonable to imagine that it can take place at so low a temperature as the highest in which my vault door, according to my own showing, has ever been placed; and so, that I have not, after all, laid any groundwork in fact for my proposition to rest on. Be it remembered, however, that I have nowhere stated, and indeed, I have not had the means of stating, what has been the highest temperature against the outer side of the door, against which side it is that the heat in the hot weather commences its action on it, and from whence, to where my thermometer was placed, on the opposite side, within the vault, was a distance of about ten feet. Besides, it has been already seen, that the quantity of heat, which will work its way through a substance in a given time, and, what is the same thing, the rapidity with which it will pass, depends, not upon the positive temperature, as indicated by the thermometer, but

ceteris paribus, on the difference of the temperatures of the air, and other substances, on the opposite sides of that through which the heat is to pass. I have read, somewhere, that in the paroxysms of greatest cold in the northernmost parts of Europe, the largest trees of the forest are sometimes split open with a noise like thunder. If this be the case, it is probably the imprisoned heat in the centre of the trees, that, having its passage out resisted by the timber, and without doubt resisted the more by reason of the absence of moisture within, at length, with the increase of the difference of the temperatures, overcomes all resistance, and forces its way out by rending the tree asunder; and this, be it observed, in temperatures, the highest of which must be lower, by far, than the lowest temperature that my vault door has ever been in. Analogous to this, although at a much higher temperature, is the case of heat leaving glass just taken from the furnace and blown into the shape of any common utensil, for instance, a decanter, and placed in the common air of the glass-house to cool, instead of being put into the annealing oven. A decanter, so put to cool in the common air, will, in a few minutes, inevitably fly into ten thousand atoms of glass. The process of annealing glass is only that of letting it grow cool by very slow degrees. And, if it be not properly annealed, it is always liable to crack, with smaller sudden changes in its temperature. In this case, therefore, the slowness with which heat leaves a particular commodity has a permanent effect on its quality. But the best annealed glass, it is

known, will always fly, (as it is termed,) both with the too sudden application of heat to it, and the too sudden abstraction of heat from it. The temper of steel itself is, in like manner, determined by the quickness or slowness with which heat is caused to leave it, by plunging it, when hot; into water more or less cold. Thus it appears, not simply that heat affects different substances differently according to their several natures, but that it affects the same substances either differently in kind, or in different degrees, according to the suddenness of its application to them, and the quantity which, in the same space of time, either penetrates into, or passes out of them; and also according to the state and condition in which the same substance happens to be, at the time of being exposed to its action. It is almost superfluous barely to mention the facts, that heat melts mercury at a temperature of what we consider as intense cold, that it melts ice at a temperature which to our feelings is still quite cold, that it melts the animal or vegetable substances which become oil, at temperatures somewhat higher, and tallow and butter at still higher temperatures, and that it volatilizes these different substances at temperatures still very different from each other. It is, too, almost idle to notice, that different degrees of heat are required for the growth of different kinds of vegetables, and that the same heat kills some by its excess, which is not nearly sufficient for the growth of others. But, to come to cases more closely analogous to the proposition I have advanced. If, in a severe frost, a cabbage

be completely frozen, and, instead of thawing it in cold water, it be put into water lukewarm, although of no higher a temperature than some of those in which the cabbage grew, it will presently become rancid. So, if a joint of butcher's meat, after being hung, as some joints may be, several weeks, when in a frozen state, be thawed in a warm room, it will very quickly become putrid. Again, if a person with a frozen limb be brought into a room of a common temperature for the limb to thaw in, instead of causing it to thaw by rubbing it with snow, the limb immediately mortifies. When it is seen that these effects are produced by the too quick application of heat, although of only common degrees of temperature; and, in the last mentioned case, at least, if not in the others, of no higher a temperature, than such as my vault door must have been frequently exposed to, any gratuitous assertion that the passage of a quick succession of heat through the timber of the door, could not have the effect I have assigned to it, on account of the lowness of the temperature, would be deserving only of utter disregard.

Supposing it, then, to be the passage of a current of heat through the substance of timber, that causes the decay in question, I will now, with the object, certainly, of gaining readier acquiescence in my proposition, but, (inasmuch as it is not incumbent on me to show how the cause of the decay acts,) only as a matter clearly of supererogation, proceed to set down the notion I have formed as to how the current or stream of heat, in working its way through

the substance of the timber, by degrees decays it, and effects its decomposition as timber. Not desiring or intending to call in question, or to intermeddle with, any particular modern doctrines respecting caloric, or latent heat, or respecting heat's being the motion of atoms, or otherwise concerning it, and, although not altogether ignorant of, yet without pretending to be very intimately acquainted with, them, I will set down only just so many of my own ideas concerning heat as are necessary for the present occasion. I think, then, that the same thing, which, when in an active form, and in no chemical combination with another thing, is called heat, and which, in this form, penetrates, and again leaves, substances, and regulates temperature, is capable of entering into chemical combination with other things, and of making with them new and distinct substances, each *sui generis*, and which substances may be either in a gaseous, or a liquid, or a concrete and solid form. More or less of heat is known to be necessary to vegetation, and I think the process of vegetation, in the growing of timber trees, causes a quantity of heat to enter into chemical combination, and in a concrete form, with other substances, and with them to compose timber. So that, I think, heat, in a concrete form, and in that form, as a part of a visible material substance, visible to the eye, and having weight, like other substances, is one of the component parts of timber, and, as well, of other combustible substances. But if heat exists in such a form, in chemical combination with one or more other substances, it by

no means follows that the combination is to be perpetual; and that there are not any means by which the several things can be disengaged from each other, and be thereupon made to assume their former shapes. My notion, then, as to how the current or stream of heat, in passing through timber, decays it, is, that when its motion is sufficiently quick, it, by degrees, disengages its sister heat in the timber from its chemical combination in a concrete form with other substances, and makes it assume its original form or shape of active heat, whereupon they both immediately pass out together. But the timber in being thus deprived of one of its component parts, becomes rotten, and is, in fact, decomposed, and what remains is no longer timber, but only some of the ingredients, or materials, which had entered into the composition of timber. The operation which I have supposed to take place, strikes me, indeed, as not being essentially different (except in there being no visible combustion) from what takes place where lighted firewood is applied to coal, and where, as soon as a sufficient quantity of heat from the burning wood has penetrated the coal, and sufficiently raised its temperature, it begins to disengage and set free the heat which has been existing in, and constituting, in a solid form, one of the component parts of the coal itself. But, I repeat, that if my notion on this matter can be proved to be completely erroneous, still it will be of no consequence, my undertaking having been, not to show how heat, by working its way through timber, decays it, but only the fact that it does so.

I have already shown, with regard to all the other things which, on my first considering the subject, presented themselves as deserving of attention and examination, that none of them are the cause of the decay. I will now dispose of what I find to be the most prevalent notion with other people as to the cause, namely, that it is vegetation, that it is fungus, that the dry rot is itself vegetation, that it is the growing of some new vegetable substance. I shall treat this notion, however prevalent it may be, rather unceremoniously, and I say that fungus, or the growing of any new vegetable, is never the cause, that is, it is never the primary immediate or direct cause, and never the necessary consequence of the decay; and that, however often it may be found present where the dry rot has taken place, or is in progress, it is only present when the decay, to some, although perhaps it need only be a very small extent, has already been effected; and that its presence is only accidental. A strange idea this, indeed, that timber's losing its strength and tenacity, and becoming a dry crumbling substance, which is often likened to snuff, is itself vegetation! That it must vegetate to undergo such a change! that rotting and vegetating are the same thing! or that vegetating is the cause of rotting, and that the latter cannot take place without the former! It might as well be said that the worms, which eat us in our graves, are the cause of our deaths, or that the maggots, which are produced from fly-blowings in meat, are the cause of its putridity, and that one has only to keep the flesh

flies from the meat, to prevent it from becoming putrid. There is no fungus as yet in or on my dry rotten vault door. But I do not know that it is improbable that there may be some on it ere long. For, now that the door has become rotten, and its surface has cracked and given way, so that the wet can penetrate to the decayed parts, fungus may, for any thing I know to the contrary, probably grow in them, as soon as warmer weather comes, and brings with it an addition of heat, so favourable, and to a certain extent, necessary, to vegetation*. And supposing fungus to make its appearance it may, and if the idea I have above expressed that the process of vegetation causes a quantity of heat to enter into chemical combination with other substances,

* This passage was written in March, 1827, which was about five months after I had made my discovery. In May, 1828, being a year and seven months after the discovery, while I was showing the vault to a gentleman versed in scientific subjects, and who is a lecturer in a public Institution in London, my son discovered on the door near the bottom, on the side within the vault, a tuft of fungus about an inch long and two or three inches broad, and as white as, and closely resembling, cotton. It remained for two or three months, and was never touched, when, rather to my surprise, in July or August, I found it had died. The remains of it are still against the door. Not the smallest bit of fungus besides this has ever made its appearance on the door to this time, December, 1828.

P. S. The fungus died probably from the continued passage of heat through the door into the vault, having, by the month of July, completely dried the door, so as to leave no moisture whatever for the root of the fungus, for the growth of which, it is reasonable to suppose that some moisture may be indispensable.

and with them to compose the vegetable, be correct, it indirectly must hasten the progress of the rot, by taking up into a chemical combination with other substances and in a latent form as heat, the heat as it comes through the timber to the side where the fungus is, and, by so doing, preventing it from raising the temperature on that side of the timber sufficiently near to an equilibrium with the temperature on the opposite side, to put a stop to the further passage of heat through it, and thus indirectly causing more heat to pass through than otherwise would. And it may produce this effect of causing a larger quantity of heat to pass through the timber, by means both of its root and its stem and leaf; and in proportion to the progress and extent of the decomposition of the timber, there will be more of the proper soil for the root of the fungus to grow in, and, consequently, there may be the more fungus, and, by means of its more extensive growth, the more extensive a conversion of heat from its active into a neutral and latent form as heat.

But, I conceive, that this is the utmost that can be said as to fungus being the cause of dry rot, and that no person can show, that it grows in timber while it continues in every part of it sound, but that some part of the timber, at least, however small, must be in a state of decay, to make it a soil for fungus to grow in, before this substance can make its appearance. But, if so, fungus, even when it is present, is not, in any ordinary acceptation of the term, the cause, but only an accidental concomitant, and at the most

only indirectly a hastener of the progress of the decay.

Having before noticed the circumstance of there being wormlike insects in the wet rotten pieces of timber in my vault, I shall only further observe of them, that these also are not the cause of that kind of decay, but are either accidentally present, or are produced, under the circumstances of the timber being both decayed and wet, and of the decayed part apparently being their proper food. If the sound part of the timber were their food, it would all have been completely eaten up many years ago, just as completely as a cheese is devoured by mites in the course of a year or two, when they have once begun to breed in it. And with respect to the dry rotten door, there are no insects in it.

CHAPTER IV.

The current of heat through the timber must be more or less rapid or considerable, and its action be continued in the whole a considerable time. Why dry rot is comparatively so seldom found in rooms having fire places in them. Comparatively new houses more subject to dry rot than older ones, and why. The quicker passage of heat through moist air. Why the more central parts of a piece of timber may be dry rotted before the more outward parts.

ASSUMING it to have now been satisfactorily shown, that it is a current of heat passing through timber, that causes the decay commonly called dry rot, I have next to insist on that part of my proposition, which says that the current or stream must be more or less rapid or considerable, and that, in the whole, its action must be continued a considerable time. Every thing that has already been stated, goes so strongly to show the necessity for such a quantity of heat, and continuance of its action, as here supposed, in order to cause the decay, that I shall instance only one other case as affording an argument and example in confirmation of what I have advanced; and that is, our comparatively so seldom finding the dry rot in our houses, or, at least, in our sitting rooms, or other rooms having fire places in them. I by no means intend to say, that it is a rare thing for builders, or persons whose business it is to do repairs to dwelling houses, to meet with the dry rot in them in particular parts;

but that it is rare to meet with it in them generally throughout the principal parts of the house, and more especially so, compared with the frequency of the presence of the same evil in ships. But if we comparatively so seldom find dry rot in our houses, notwithstanding, in our sitting rooms, during the winter season, the temperature is often kept a number of degrees higher than that of the outer air, and it is commonly also considerably higher than that of any adjoining passage within the house, it may be regarded as pretty certain that it requires the action of a considerable current of heat, continued a considerable time in the whole, or in other words, it requires a large quantity of heat, in the whole, to pass through timber ordinarily well seasoned and sound, to produce the decay.

But, it is possible, that what I have last stated may be attempted to be turned into an argument against my proposition, by objecting that it goes to show that the passage of heat through the timber is not the cause of the rot. I will, therefore, point out the reasons, why, notwithstanding our sitting rooms are in winter commonly of so much higher a temperature than the air out of doors, we so seldom find the dry rot in them. The first reason is, that timber, by being exposed to heat brought into contact with it by the circulation of dry air, gradually becomes very dry, and, in so becoming dry, it shrinks, or contracts, laterally, into a smaller space than it occupies at first. Hence, notwithstanding the rooms of a new built house may,

at first, from the window sashes, doors and door-frames, boards of the floor, skirting, and other parts composed of timber, being made to fit close, be very air tight, yet, in a little while after fires have been kept in a room, the lateral shrinking of the timber will open numerous passages for the admission of air, little suspected, perhaps, by those who inhabit the house. Some years ago I took a set of chambers in an old wainscotted building in the Temple, and on the approach of winter, finding my sitting room, which was a large one, to be very cold, I sent for the carpenter to stop out the wind. The journeyman who was sent to do the work, and who was directed to bring a quantity of cartridge paper and paste, was very handy on such occasions. But, in consequence of the building being wainscotted, apparently to the very uppermost rooms, and the wainscot being hollow throughout, I well remember, that, in spite of his and my own endeavours to find out and paste over every crevice, I had to send for him five times before we had succeeded in making the room moderately warm. And, after all, I discovered that a current of air was still entering at the fire place, for about the length of three feet, through a narrow chink or opening between the wainscot and the stone chimney jamb. It is, indeed, surprising with what velocity and force air will rush through a key hole, or other such opening, or under a door, into a room, in other parts air tight, having a brisk fire in it. But, as I have said, there will, in a room in which a fire is commonly kept, soon be openings in various places for the air

to enter at. It will certainly enter at the window sashes, and all round between the door and the door-frame, and, probably, through one or more unperceived crevices, occasioned by the shrinking of the timber, in the joinings of the door-frame itself; and at these places in particular, not to mention crevices between the boards of the floor, or between the floor and the skirting, or behind the window shutters, or other places. And hence it is, that list and sand bags are so often required for windows and doors, in order to keep a room moderately warm. But the effect of the continued entrance of currents of air into a room with a fire in it, is, to relieve the heat from the necessity, (if I may use the expression,) of forcing its way out, in consequence of its continued increase, through the wainscoting, or doors, or other parts composed of timber. For the heat, on the entrance of the air, penetrates into and mixes itself with it, and is at first necessarily employed in raising the temperature of the air, instead of passing through the timber. On mixing with the air it renders it specifically lighter, and rises, in the greatest quantity, with it to the ceiling, where a part of the heat makes its way out through the plaster and laths of the ceiling, into the spaces between the joists above, where it is most commonly carried away and dispersed by another circulation of air. Another part of the heat at the same time passes out through the glass of the windows. But the great protection of the timber in this case from having such a considerable passage of heat through

it as to cause its premature decay, is, that the air on becoming expanded and specifically lighter on receiving the heat into it, is, by the mere law of gravitation, in constant circulation round the room, and a part of it continually passing off up the chimney, and carrying off a portion of the heat along with it. The consequence of this is, that there is, in no part of the room, a quantity of heated air remaining lodged against the timber, and causing a stress of heat against it, and accumulating to the point at which it overcomes the resistance of the timber, and forces a passage through it; but which must happen where heat continues to be generated, and there is either no opening for the admission of fresh air, or, if there be such an opening, no chimney or other second opening for the passage of it out. For without a second opening the room or other place can only be once filled, without having a regular succession of air, or, consequently, a regular passing off of the heat, with the air, out of the room. But, in rooms in which there are such a circulation and change of air and heat as have been above described, and where the timber is thoroughly dry, and of any considerable thickness, from the resistance which this substance presents to the passage of heat through it, as the heat has other vents, and does not accumulate in such a degree as to become irresistible, only a small quantity, if any, will work its way through the timber.

A still further reason why we comparatively so seldom find the dry rot in our sitting rooms, is, that heat passes out of dry air in order to enter any

body of a lower temperature, much more slowly than it leaves air saturated with moisture for the same purpose. Again, the very circumstance of a room with a fire in it remaining of many degrees higher a temperature than an adjoining passage at the opposite side of the door, is a proof that but little heat is working its way through the door. For, otherwise, it would raise the temperature at the outside nearer to an equilibrium with the temperature within. If much heat were coming through a door, it would necessarily considerably raise a thermometer placed against the door, as it issued from it. Or, to put the same thing differently, as the same heat cannot be at the same time both in the room and at the outside of it, if heat, as it came from the fire, passed quickly out through the door, the temperature within the room must be proportionably lowered, and it could not, as supposed, be of many degrees higher a temperature than the passage, or other place, at the outside of the door. It is, therefore, shown, that our so seldom finding dry rot in our sitting rooms, affords no argument that it is not the passage of heat through the timber, that, when the dry rot does take place, causes the decay.

What has latterly been stated goes, also, a good way towards accounting for dry rot appearing as frequently, if not more so, in comparatively new houses, than in such as have been built many years; namely, that it is from houses being, at first, more air tight, and from their timber being new, and not so completely seasoned, and from its pro-

bably containing within it more or less either of foreign wet, or of its own sap; all of which circumstances render it liable to the quicker a passage of heat through it, with the same difference of temperatures on its opposite sides.

Moisture of the air on either side of the timber, it may be observed, will accelerate the passage of the heat through it, even though the moisture do not penetrate the timber itself. If the moist air be on the colder side, it will accelerate the passage of the heat through the timber, in consequence of the heat, on issuing out on that side, and coming into contact with the air, passing into it, and uniting with the moisture suspended in it, and passing away, more rapidly than it will pass through dry air, and the colder side, consequently, still continuing to be kept proportionably cooler than it would be, if the air on that side were dry, at the time of the heat entering it. If the moist air be on the hotter side of the timber, it will cause the passage of the heat through it to be the quicker, by bringing the heat more quickly into contact with the timber, in order to penetrate, and pass through it, to raise the temperature on the other side.

The property of heat to pass through a substance when saturated with wet, with greater rapidity than through the same substance when dry, also shows why a piece of timber, if placed so as to have a current of heat passing through it, may possibly be decayed in its interior and more central parts, before being decayed in its more outward parts; inasmuch as a piece of timber at the time of its

being exposed to the heat, may be comparatively or completely dry to a certain depth inwards, whilst it has a quantity of wet in its centre, through which the heat, when it reaches it, will pass with greater velocity, and will pass through it lengthwise the timber, if prevented by the superior dryness of the more outward parts from passing out crosswise with the increased rapidity. But in addition to the mere increase of velocity in the passage of the heat, the wet part of the timber may have less power of withstanding the peculiar action of the heat, whatever that action may be, that effects the decomposition. Again, a piece of timber so dried to a certain depth only, may, possibly, have been so far dried too quickly, and so as thereby to have closed the pores of the dried part in such a manner as to have shut up the remaining wet within a substance too close for it ever to completely exhale through. And if so, as long as the timber lasts, whenever a current of heat in its way through it, reaches the wet, as it will have both to unite with and again part from it, before leaving the timber, and in mixing with the water it will have a tendency to take it up and separate it into its elements of oxygen and hydrogen, or to put it at least into some gaseous form, it will exercise some mechanical force on the water, and cause some motion in it within the timber; and hence, also, it would seem, that it must necessarily cause the action of some mechanical force towards separating the component particles of the timber itself.

CHAPTER V.

The kind of situations in which timber must be placed in order to have a current of heat passing through it. The principal circumstances on which the quantity that passes, depends. The progress of the decay dependent on the rapidity of the passage of the heat, and the length of time it passes, and on the kind and quality of the timber. Circumstances on which the superior quality of timber, for its kind, appears to depend.

THE matters which have gone before, enable me now to describe, in a general way, both the kind of situations in which timber must be placed in order to have any rapid or considerable current or stream of heat passing through it, and the principal circumstances by which the quantity that will pass will, in general, be governed.

First, then, with respect to the situation in which timber must be placed in order to have a current of heat more or less rapid or considerable passing through it, this may happen, first, if the timber be in close contact with a solid substance, which alternately receives and gives out heat with changes in the temperature of the weather, but which is so placed that the heat cannot enter or leave it, otherwise than by passing through the timber. For instance, if an air tight platform of timber of considerable dimensions were placed in close contact with the ground, the heat for raising and lowering the temperature of the ground with

the changes of the seasons, must work its way through the timber. So, although air, or water, be in immediate contact with the timber on both its sides, heat must work its way through it with differences in the temperature on its opposite sides, if the timber be so placed that the heat cannot otherwise pass from the one side to the other. And this will be the case, if the partition or structure of timber be itself air tight, and there be on one of its sides an enclosed place, also air tight, into or from which the heat cannot pass through any other part so readily as through the timber, as is the case with my vault door. It is the same with the timber of a water butt for the common uses of a dwelling house, and more extensively so, if, as often happens for want of the ball cock being in proper order, the water continues to run into the butt, and runs off at the waste pipe, after the butt is full; and this, whether it be kept within doors or in the open air. For, in either case, the water entering it will generally be of a different temperature to that of the air at its outside; and the heat, for approximating the temperatures to an equilibrium, will have to pass through the wood. The differences of temperature, however, will not be liable to be so great, if the butt be kept within doors; and, in that case also, a smaller quantity of heat will pass through the wood, because the air of the house will commonly be both dry, and of a temperature somewhat higher rather than lower than that of the water within the butt, whereas the outer air would commonly be hotter in mid-day,

and considerably colder at night; besides being subject not only to be saturated with moisture, but to part with it in the form of rain, hail, and snow. Water butts, however, if much water pass through them, whether kept within doors or in the open air, are never very durable. A painted water butt less than seven years old, suddenly bursted recently, and inundated the back area of my house. It was, when first set up, a very sound wine pipe. But, besides water butts, all casks for containing liquids, if of large dimensions, must be subject to the passage of a more or less considerable quantity of heat through their timber, except where they are kept in a dry cellar, the temperature of which varies but little and very slowly from winter to summer, and summer to winter. And, in order to have such a cellar it must be within the house, and be more or less under ground, or its walls must be of unusual thickness, and both the walls and its ceiling or roof be of materials the most impervious to heat. For the like reason of its being exposed to have a more or less rapid current of heat passing through the timber, a meshing tub, if in frequent use, must be a utensil of comparatively little durability. But, of course, according to my doctrine, it will decay fastest in the parts exposed to the passage of the greatest quantity of heat. And on this account, I apprehend, its bottom will last longest, and it will decay fastest behind the hoops, if iron hooped.

But if heat coming to timber, come to it in the air, and the timber be so situated as that the air can freely pass from one side of it to the other with

sufficient quickness, by passing either over, or round it, or through apertures sufficiently large in the timber itself, and can then pass away from it, it will so pass, and the heat along with it, accordingly; and the latter will not work its way in any current or stream through the substance of the timber, but will only penetrate it in the requisite quantity to raise the temperature of the timber itself, to the same height with that of the heat. To cause a current of heat, which comes, or is brought, in a body of air into contact with timber, to work its way through it, the air must, therefore, either be completely separated from the air or other substances on the colder side of the timber, as in the case of the air on the opposite sides of my vault door; or, if there be no complete separation, either the hotter air on the one side, or the colder air or other substances on the other side, must be contained in an enclosed place, and have only such a communication with the opposite side, as that either by the want of more apertures than one for the passage of the air, or by their smallness, or their particular situation, either no regular succession or current of air, and consequent passing off of the air with the heat in it, can take place from the one side of the timber to the other, or not a succession sufficiently quick to so relieve the timber from the stress of heat against it as to prevent it from working its way through it in a quantity more or less considerable.

Secondly. It being before shown that timber always opposes some resistance to the passage of

heat through it, and that with the same difference of temperatures on the opposite sides of the timber, heat will pass from or into some kinds of substances to enter or leave the timber much more rapidly than from or into other substances, it follows that in some cases, with the same difference of temperatures on the opposite sides of the timber, a current of heat will, and in others will not, be passing through the timber. But, where a current of heat is working its way through timber, the quantity that will pass in a given time will principally depend, first, on the difference of the temperatures on the opposite sides of the timber; secondly, on the dryness or moisture of the air on each side; thirdly, on the wetness or dryness of the timber itself, whether on its surface only, or in its interior, or both on the surface and in the interior; fourthly, on the kind of substance generally on either side with which the timber is in immediate contact, as, for instance, whether it be metal, or stone, or any other substance through which heat readily passes, or the contrary; fifthly, on the thinness or thickness of the timber; sixthly, on the kind of timber; seventhly, on its quality for its kind; and eighthly, in so far as respects different parts of the same piece, on their position with regard to the direction or setting of the stream of heat towards it. And the quantity that will pass through in the whole, will, as before observed, depend both on the quantity, or supply, of heat that there is on the hotter side, to pass through to raise the temperature of the colder substances on the opposite side, and on

the quantity of those substances, and the quantity of heat, which, according to their several natures, they will take for having their temperature raised to the destined point; and which will be the point as near to that at which the temperature on both sides would be the same, as the hindrance of the timber to the passage of the heat through it will admit of.

Supposing the quick passage of heat through timber to be the cause of the decay, the progress of the dry rot must depend, in each particular case, on the rapidity of its passage, and the length of time, whether with or without intermissions, that it passes in the whole. And what has been stated will afford pretty satisfactory general means of judging of the activity of the cause of decay in most cases that may arise. The progress, however, will, ceteris paribus, be quicker or slower, according to the kind of timber, and its quality for its kind, even supposing each sort to be equally dry and free from foreign matter, and to be placed in similar situations. Experience shows that some kinds of timber can oppose much greater resistance than other kinds to the decomposing action of the heat; oak, for instance, much greater than elm, and African or Indian oak, or teak greater than common oak. And those kinds which can oppose the greatest resistance to the decay are, I believe, such as are of the closest texture and specifically heaviest; and these qualities in timber of the same kind seem, in some degree, to depend on the intensity of the heat of the climate, and the dryness and free circulation

of the air of the particular place in which the tree grows. And the way or means by which these kinds of timber oppose their superior resistance to the cause of the rot, may be, and doubtless is, that they both present a greater obstruction to the passage of at through them, and, where, from any accidental cause, (such as their opposite sides happening to be exposed to a much greater difference of temperatures than those of a piece of timber of a more porous and a specifically lighter kind,) an equal quantity of heat passes through them, that their component parts have a greater degree of fixedness, or stronger chemical union, and require a more powerful action to disengage and set them free from their state of combination with each other.

CHAPTER VI.

Shipping is peculiarly exposed to the action of the alleged cause of dry rot. How soon a ship, whilst building, begins to be exposed to it, and why. A vessel is the more exposed to it, the closer it is kept shut. Also, the larger the vessel. So likewise by being coppered. So by having a heating cargo or a numerous crew on board. The upper works and parts near the water line are exposed to the greatest differences of temperature, and they decay the soonest. The floor timbers are the least exposed, and they remain sound.

I SHALL now direct my observations more particularly to the case of ships, and other vessels for the purposes of navigation, as subjects of dry rot, and show that they are to a peculiarly great extent exposed to the action of what I have assigned as the cause of the decay. And I shall leave it to the reader, who is conversant with shipping, to turn in his mind the principal matters which have already been, and those which will be advanced, and satisfy himself how well they tally with what he knows of actual instances of dry rot on board ship. On such a consideration of the subject, every reader, whose object is truth, will quickly see that the assigned cause of the decay is consistent with the facts of all the cases of dry rot within his experience, and that it alike accounts for, and is confirmed by, most of the phenomena which accompanied them.

A ship, then, is exposed to the cause of the decay from the moment it is so far enclosed or shut in, that the common air of the atmosphere cannot,

with every change of temperature of the weather, circulate freely on both sides of all the timber of which it is composed. And this will be the case, to a certain extent, while the vessel is still on the stocks, and even before it is decked or covered in, if it be completed in its bottom and sides all round to any considerable height. For in such case, as to so much of it as is so completed, it is become a well, from which the air within it cannot be removed, on every change of temperature, either by the wind, or by the natural action of any other agent. If the change be from colder to warmer, and the increase of temperature be sufficiently great, a part of the heat of the now hotter air on the outside, will work its way through the timber of the lower parts inwards. For the outer air, in consequence of its becoming specifically lighter, in newly becoming hotter, cannot descend to the bottom on the inside, and displace the heavier and colder air there, and force it out over the sides, and take its place. The heat, therefore, for raising the temperature of the air within, must and will, when the difference of the temperatures is sufficiently great, force its way inwards through the substance of the timber; and, commonly, first, in the lower parts of the vessel, and in those parts, because there the difference of the temperatures will commonly be the greatest. But the converse of this will not so readily take place on a change of weather from warmer to colder. For the colder air which is now over the uncovered shell of the vessel, from being heavier than the warmer air

below, will have a tendency to descend into and displace the latter. It will not, however, altogether displace the warmer air below, so as to force it up and out over the sides of the vessel, but, as it descends, it will receive a part of the heat from it, and, by such means, being a little warmed, and become a little lighter than the air immediately over it, and next in succession for descending, the latter will, by descending to take its place, either cause it to reascend a little, or stop its further descent, till the heat it has received leaves it to pass into that which is above it, when it will begin to redescend; and, thus, it will, by degrees, by a kind of oscillating or conflicting motion, without, perhaps, any considerable part of it actually reaching the bottom, pass off the surplus or excess of heat within the shell of the vessel. And by this process, when no part within the frame of the vessel is decked or covered over, the surplus quantity of heat within may, most commonly, if not always, in, at least, any changes of temperature of the air that take place in England, pass out upwards into the open air with sufficient quickness to prevent any of it, or any considerable part of it, from working its way through the timber of the sides. This, however, must depend upon various considerations, such as the thickness or thinness of the timber, with its greater or smaller power of resistance to the passage of heat through it, the height of the column or body of air contained within the frame, or shell, of the vessel, and the suddenness and extent of the change of the temperature.

As soon as a vessel is covered in, it becomes exposed to a more extensive action of the cause of the dry rot in the passage of heat through its timber, both on a change of temperature from cold to warm, and a change from warm to cold. The heat will sooner work its way through the timber inwards, on a change from cold to warm, than outwards on a change from warm to cold, for the reason mentioned in the first case put. But it will now also, on a change from warm to cold, work its way through the timber outwards; and this, even although the hatchways may be left open. For such openings as the hatchways of a vessel, which bring the colder air into contact only with the upper surface of the warmer air within, when it is considered how small a proportion they bear to the whole area of the deck, and the enclosed space within, it will easily be conceived, are by no means large enough for the excess of heat contained in the interior, on any considerable change of temperature of the weather, to pass out upwards with sufficient quickness to prevent any of it from going out through the timber. And this, it will be more readily seen, must be the case, when we reflect on the jostling kind of action going on between the different particles of air, when colder air has to descend into a quantity of warmer, situated immediately underneath it, and contained in any receptacle of the nature of a well, (that is to say, any place close at the bottom, and all the way round its sides,) in order to cause the excess or surplus of heat to pass out upwards, through the same place or aper-

ture through which the colder air has to descend. The passing of the heat out in such a case, must be comparatively very slow, inasmuch as there is, properly, no circulation or change of air, but the same particles of air in a great degree continue to be the medium by which the heat has to pass out, by moving from one to another while in their to and fro or conflicting motion.

It may next be observed, that the closer the vessel is kept shut, the quicker, on any given difference of temperatures in its interior and at the outside, will be the passage of the heat through its timber; because, supposing it to be kept quite close, the heat will have no other way of entering or leaving the vessel.

The next observation worthy of being made, is, that the larger the ship, the larger, ceteris paribus, compared with the area or surface of the shell, or outer parts, will be the quantity of solid contents within it, that alternately receive and give out heat on changes of temperature; and, consequently, the greater will be the quantity of heat that will work its way through any given surface or portion of the timber, both into and out of the vessel; and the more, therefore, will it be exposed to the action of the cause of dry rot.

Again, a heating cargo, or any other substances or living creatures on board, generating and giving out heat, and the heat from the persons of a numerous crew, when below decks, will necessarily add to the quantity of heat within, which will have to work its way through outwards. So, again, heat

may ignorantly and needlessly be caused to pass through the timber in different parts of the vessel by artificial means; as, by the unnecessary washing of decks, and thereby, whenever the outer air is the colder, causing the heat in the air in contact with them on the under side, to leave the air and penetrate up through the timber. In like manner, the placing of any substance of any of those kinds which are commonly, but, in my opinion, from what I have lately observed of the nature of heat, not very properly called great *conductors* of heat, (I allude principally to metals,) in immediate contact with the timber, whether in the inside of the vessel, or on the outside, must tend to increase the passage of heat through it. The copper on coppered ships must, therefore, tend to produce this effect. Accordingly, doubtless, from its having been observed that the copper when in immediate contact with the timber "decayed the wood," it has, I find, been the custom to put a layer of brown paper between them. This, no doubt, has assisted to preserve the timber; although, I apprehend, no person hitherto has known why. But the reason is, that brown paper is composed of a material, (old rope,) which is very impervious to heat, and which, therefore, greatly protects the timber from having so quick a passage of heat through it, as would otherwise inevitably be occasioned by the copper, on there being any material difference of temperatures at the opposite sides. Iron or other metal bolts or nails, if in parts of the vessel where the opposite sides of the timber are exposed to be in materially different temperatures,

must have the like tendency; but the effect will, perhaps, be diminished, if they go completely through the timber, and are of the same or nearly the same thickness at both their ends. There are two or three old iron staples that, at one time or another, (I know not when,) have been driven into the brickwork of the arch of my wine vault, and which are now much rusted; and these always have a drop of water suspended to, and, as it becomes too heavy to continue suspended, dropping from them, whenever the temperature of the vault is higher than that of the ground above. And the water makes its appearance on these staples, in consequence of the heat passing through them out of the vault more quickly than through the brickwork, long before there is any appearance of wet against the latter. Metallic paint on timber, the opposite sides of which are in different temperatures, produces the same effect of causing heat more readily to pass through it. I have lately seen on my own premises an instance of this, which is really curious, both from its showing how much more rapidly the paint causes the heat to pass through, and the great nicety with which the quantity that passes, as indicated by the quantity of water left deposited on the hotter side, is governed by the thickness or thinness of the timber. But it would occupy too much room to enter into the particulars of this case here.

But again, some parts of vessels are exposed to much greater differences of temperature than other parts. The upper works, and the parts near the level of the water line, are exposed to the greatest dif-

ferences, and the floor timbers to the least. And, accordingly, the former decay more or less rapidly, while the latter remain sound; and, as I have been informed, are even used over and over again for new vessels. It is evident, therefore, that ships always are, and, unless the proper and adequate means of prevention be known and had recourse to, always must be exposed to the action of the cause of dry rot, with every material change in the temperature at the outside of the vessel, whether of the air or the water, and in whatever way such change be brought about; and this, exclusive of any action of it arising from artificial or accidental causes in the interior. And there can be but few days in the year, in which, in the course of the twenty four hours, such a change of temperature as to cause some degree of flood and ebb of heat through the timber of some part of the vessel will not take place.

The knowledge of what I have latterly been advancing, with that of the kind of timber a vessel is built of, and of all the facts in her history relative to the countries she has been trading to, and the kinds of cargoes she has been carrying, or other kinds of service she has been employed in, with the treatment she has met with from the master and crew, will, I apprehend, enable the reader, who is conversant with shipping, pretty satisfactorily to account for the appearance of any dry rot that may make its appearance on board her; and, supposing it not to be as yet very extensive, for its appearing in the particular parts in which it is found.

CHAPTER VII.

Of the proper nature of the remedy for the evil of dry rot, &c.; with preliminary matters; and of the principles of the author's patent invention. The circumstances that decided him on undertaking the subject. The rapid decay of ships in the navy. Particular anecdotes of. Phenomena of dry rot hitherto inexplicable. King's ships sometimes cross the ocean home with their quarterdecks rocking like new made hayricks. A trial at law, arising from a merchant ship having quickly become dry rotten. The acknowledged ignorance of the parties of the true cause of dry rot. Motion in the House of Commons for the Navy Estimates." The admitted heavy charges in them for "materials," and "artificers' wages." The rapid decay of the vessels attributed by the mover to a mistaken cause. Contrivances that might prove palliatives, but only palliatives of the evil. Another kind of palliative in theory, but unsafe. A quality essential to the proper remedy. The principles of the writer's patent invention for preserving decked shipping from dry rot, &c. Its leading principle is to keep what approximation of temperatures to an equilibrium, where, and by what means. Why this is made the leading principle. A supply and change of air, the means used, and why. The supply or quantity to be a regulated supply, and why. The means provided of introducing the air only into particular parts of the vessels, and down only to particular depths at pleasure.

THE cause of dry rot being known, the next subject for consideration is how to provide a remedy for the evil. I have, with much pains, succeeded in devising and perfecting the natural, and the only natural, proper, effectual, and cheap remedy, as respects the timber of all kinds of decked shipping. But before proceeding to give an account of my

invention, I shall shortly narrate the circumstances which induced me, a practising lawyer, to take up the subject as matter of business, and, in the result, as the only course which afforded me a prospect either of securing to myself whatever of merit belonged to the discovery, or of reaping any advantage from it, to make my invention the subject of letters patent.

Within a few weeks after making my discovery, I heard from a young gentleman connected with the navy, and who, on the subject of dry rot being casually mentioned, appeared to take an interest in it, several anecdotes of particular instances of dry rot in king's ships. The anecdotes, of course, chiefly related to points which appeared extraordinary, or inexplicable; such, for instance, as two vessels being built of the same kind of timber, and under exactly the same circumstances, and one of them quickly becoming rotten, while the other remained sound; or two vessels being built together of different kinds of timber, and the one which was expected to last the longest being found, on trial, so rotten, as that, on the first stroke with the mallet, mallet and all flew out of the workman's hands, and went through the ship's side into her, while the other vessel proved sound. He mentioned, also, that this or that piece of timber would be found quite rotten, while the piece next it would be perfectly sound. I remember his also remarking how often it happened that king's ships were compelled to return from foreign stations before their time of service was out, in order to refit, and that sometimes

they had to cross the Atlantic, in their way home, with their quarterdecks, and all their aft parts, rocking like new made hayricks. Never having, till then, heard mentioned any particular term during which ships of war commonly lasted, if I had been asked what I supposed was the average duration of a first rate man of war, I should, probably, from knowing of what large dimensions the timber composing such a vessel must be, have guessed sixty or a hundred years. But I learned to my astonishment, (although I do not recollect whether it was from this gentleman,) that first rates sometimes lasted only four or five years, and sometimes were rotten when launched; and that their average durability was only eight or nine years. Soon after this, in January, 1827, I was present at Guildhall, London, at the trial of an action at law, which arose from a vessel, called the Benson, having, in the course of a voyage to the East Indies and back, been found dry rotten some five or six months after her leaving England; which, although, in the result, it turned out to be unnecessary, it was intended to contend, was proof that she could not have been seaworthy at the time of her setting sail to commence the voyage. In this action the defendant's counsel gave a detailed statement of various opinions, which were entertained by different persons, respecting the causes of dry rot; all of which opinions, I saw in an instant, were erroneous; and which, indeed, were acknowledged not to have completely ascertained the true cause. In the following month of February the "Navy Estimates" were moved

for in the house of commons, and I saw how large, considering the present reduced scale of the navy, were the sums voted for "materials," and "artificers' wages," which, together, including credit for proceeds of sales of old stores, amounted to upwards of a million and a half; and this, independently of the collateral charges arising from the same cause of the little durability of the vessels, and set down under other heads. On this occasion the newspapers reported the honourable member who moved the estimates to have admitted the largeness of the amount, and to have attributed it to "the perishable nature of the materials." No, thought I, Mr. Comptroller, it is not owing to "the perishable nature of the materials," at least, not in the sense in which you are using the expression; but it is owing to the vessels being always exposed to an unseen, but sure and swift cause of premature decay, of which neither you, nor anybody but myself is aware. These circumstances induced me to take up the subject as matter of business, and to set about considering the proper remedy for the evil. And, afterwards, discovering that the preservation of various kinds of goods on board ship from damage by heat, was an object of equal importance with that of the preservation of the vessel itself from dry rot, and that both evils were to be remedied by the same means, I finally resolved fully to mature my invention, and obtain for it the protection of letters patent.

But to proceed to the subject of the remedy for the evils in question. The cause of dry rot being

known, and it being such as has been above explained, it is easy to imagine expedients that theoretically, at least, and possibly also in practice, might prove useful as some sort of palliatives of the evil. Thus, the passage of a more or less rapid or considerable current of heat through the timber being the cause of the decay, it might afford it some protection, to place in immediate contact with the timber any durable substances more impervious than itself to heat. For instance, lining the timber with cork, canvassing and papering it to a considerable thickness with brown or other unsised paper, covering it with Russia matting, or with well fulled cloth, or even thatching it with reed or rushes, so long, at least, as the respective things remained dry, might, and in temperate climates probably would, lessen the quantity of heat passing through the timber. But even supposing the use of any one or more of these things on board ship were not objectionable, on account either of their want of sufficient durability, their expense, the increased danger from fire, or the room they would take up, and the harbour they would afford for dirt and vermin, they still would, at the most, be but palliatives; inasmuch as they would only go to the diminishing of the effect produced, instead of to removing or stopping the action of the cause of the decay. They would be like a padding to deaden the force of blows, instead of something to put a stop to them. Besides which, they would be more or less liable to shut in moisture in contact with the surface or within the timber, and when that

happened, they would indirectly cause heat to pass through it, with the same difference of temperatures at its opposite sides, with, perhaps, twenty fold rapidity; and thus, while directly they had a tendency to lessen, indirectly they might tend to aggravate the evil.

It would also, primâ facie, be a palliative, and even something more in its nature than a mere palliative like the former, if, instead of making the whole of the ship's sides and bottom and decks of timber, there were used, at stated distances, large plates of iron or other metal, as being substances more quickly pervious to heat than timber, for the heat to pass through into and out of the vessel by turns, instead of working its way through the timber. But, besides that having recourse to such a contrivance would, in proportion to the extent to which metal, instead of timber, was made use of, be of the anomalous character of a professed remedy for an evil to a given material by the disusing of the material which was to be preserved, I apprehend it to be unnecessary to insist by argument on the want of safety, or the impracticability, or inexpediency of using metal, in any considerable quantities, instead of timber, for the bottoms, sides, or decks of vessels; and more especially, for so using it at any considerable depth below water.

These considerations point out that the natural and proper remedy for the evil of dry rot in shipping must be something different from either of the descriptions of things which have been noticed; and that it ought to be something, which, while directly

it will put a more or less complete stop to the action of the cause of the decay, will not indirectly have a tendency to excite it. I have accordingly devised such a remedy, the leading principle of which consists in keeping, by means of the introduction into the vessels and passing off again of a regulated quantity, or supply, of the hotter or colder outer air of the atmosphere, as the occasion requires, the temperatures on the opposite sides of the timber sufficiently near to an equilibrium to prevent the passage either of any current of heat through it, or, at least, any such considerable current as will be sufficient to work its decay within any other than a remote period of years, compared with the present greatest durability of decked shipping. And I will now describe the invention itself for effecting the proposed objects, and state the reasons for it, both as a whole, and for its several parts, where the reason is not too obvious to require mention.

I have made the keeping of the temperatures at the opposite sides of the timber nearly approaching to an equilibrium, the leading principle of all in my invention, because it is only the property of heat to seek to distribute itself so as to equalize the temperatures of contiguous or neighbouring substances, that causes it to leave one substance to penetrate, or penetrate and pass through and out of another in contact with it into a third; and this implies in such cases a previous difference in the temperatures of the different substances. Consequently, equalizing the temperatures on the opposite sides of

a substance will prevent the passage of any heat through it; and keeping the temperatures on the opposite sides of any substance which is comparatively little pervious to heat, as is the case with timber, within a certain approximation to an equilibrium, will have the same effect. And, although the temperatures may not happen to be brought sufficiently near to an equilibrium to prevent any heat from passing through such a substance, every additional degree of approximation will lessen the quantity that passes, till, at length, it will be only such as to be nearly or quite harmless; while, with such a substance, there may still be several degrees difference of temperatures on its opposite sides.

My reasons for using the air of the atmosphere as the medium, or instrument, of causing the approximation of temperatures to an equilibrium, are these: first, heat readily enters, and again leaves, atmospheric air, with any sensible differences of temperature in the substances in contact with, or near to which, any body or volume of it happens to be placed. Secondly, heat, on entering atmospherical air, expands, and makes it specifically lighter; and, in so doing, it not only puts it in a certain degree of actual motion within itself, but tends to cause, in certain circumstances, by the mere law of gravitation, a continued circulation and change of air; by our availing ourselves of which in the right way, heat may be passed off from the interior of a vessel, without the necessity for using any mechanical or other artificial force for the purpose. And, thirdly, air which is not already

charged with as much moisture as it can hold suspended in it, in its actual temperature, on coming in any current or stream into contact with, and passing off again from, any wet of a lower temperature that happens to be deposited against the surface of any substance, gradually takes up the wet into it, and carries it off along with it; and thus, by degrees, it dries the substance: and it therein has an opposite effect to the hurtful one that might be occasioned by the before mentioned palliatives, in shutting in and preventing the evaporation of the wet.

But the quantity or supply of air is to be a regulated quantity or supply. And the reason for this is, that an unregulated and unmeasured supply may be such as to produce the evil intended to be guarded against, by raising or lowering the temperature at that side of the timber into contact with which it is brought, to such an extent, as to cause a current of heat to set through the timber from the opposite side to that which was at first of the higher temperature.

The temperature of the outer air and water not being subject to our control, it follows, that the air to be made use of, towards equalizing the temperatures on the opposite sides of the timber, must, as before stated, be introduced into, and again passed off from, the interior of the vessels. And the temperature, as well of the interior of vessels as of the outer air and water, being liable to be different in different parts, and at different depths, at the same time, it follows, that, for approximating the temperatures

to an equilibrium at the opposite sides of the timber, at every part of it, it may be necessary and proper to introduce the air, which is to be introduced and caused to circulate in the interior, and to be passed off again, only into particular parts of the vessel, and down only to particular depths within it.

The temperature in the interior of a vessel being liable to be sometimes hotter, and sometimes colder, than that of the outer air or water, it follows, also, that the air to be introduced and passed off again, will sometimes be hotter, and sometimes colder, than that which is already within the vessel. And the producing an approximation of temperatures at the opposite sides of the timber implies, of course, that the temperatures at each side are to be previously ascertained. And this is to be done by means of thermometers; and, consequently, the providing and using of thermometers, in combination with the other means of attaining the proposed objects, form an essential part or member of the invention.

CHAPTER VIII.

Commencement of the description of the invention itself. It consists of a combination of alterations in the vessels, and of apparatus and machinery. The alterations in the vessels consist of additional openings, where, and for what purposes. The apparatus and machinery are for ascertaining the temperatures, and introducing and passing off hotter or colder air, when and where. For introducing, in general, colder air, a hollow shaft, with a moveable part to stand when raised, above deck, &c. Apertures in the moveable part, with sliding shutters, to admit the air and regulate the quantity. The shaft, where situated. The colder air to be conveyed, down to what level. Hollow trunks attached to the shaft, for conveying the air whither required. Different orifices in the trunks, with hatches to regulate the passages for the air. When an additional set of trunks. The apparatus described not alone sufficient for what purposes. To ensure the right current of air, a new invented valve. The material of its working part. The valve where placed. The moving force for putting it in action. The before described apparatus will not always act, and when not, other means, after mentioned, resorted to. Apertures for discharging the heated air. Chimnies placed over them. Revolving chimney tops, to discharge the air in the direction of the wind. For getting at valves in long voyages, &c. open lattice works, with a folding rod, for passing the valves up and down. For goods liable to damage by heat, perforated battens to preserve passages for the air. To ascertain the temperatures, thermometers kept placed where. Grooves for letting them down to the assigned stations. Ascertaining the temperatures of the water, at what different depths. The removal of heavy gases from the interior.

I now proceed to give a description of the invention itself, which consists of the following combination of alterations in the vessels, and the following apparatus and machinery to be used on board of them for attaining the ends proposed.

The alterations in the vessels consist in providing, in addition to the present openings or entrances into them, separate apertures for the entrance, and passing off again, of the air which is to be introduced, with other openings in the interior, for its freer circulation from one part to another while within the vessel, and to prevent it from lodging between the beams, &c. in contact with the under side of the planks of decks. The apertures for the entrance and passing off of the air are, of course, to be made in the most convenient situations, and to be placed at the most proper distances from each other, for best effecting the desired objects.

For the introduction, in general, of colder air, when it is required to pass off heat from the interior, an opening of adequate dimensions is to be made in the deck, or upper deck, as near the middle of the vessel as conveniently can be, and is to be continued down, through every deck, to the bottom of the hold. In this opening, the best form for which will be square, is to be constructed a hollow shaft, with air tight sides, composed of timber, or other materials, as little pervious to heat as can be found, reaching down sufficiently low to convey the air to near the lowest level from which the passing off of heat can be required; and which sometimes, more especially in the larger classes of

vessels, will be as low down as the level of the kelson in midships. And in some cases, as, for instance, on a vessel's leaving the Floridan gulf stream, and quickly getting into water many degrees colder, it may be requisite, if practicable, to introduce colder air down quite to the bottom of the hold.

For better ensuring a sufficient supply of air, and for regulating the quantity admitted, this shaft is furnished with a moveable part, constructed so as to fit and slide up and down within it, and so as, when raised up, to stand a certain height above deck. This moveable part is to be furnished with an aperture in each of its sides for the entrance of the air, and each aperture is to be provided with a shutter, or sash, made to draw up and down, for regulating at pleasure the size of the opening, and, consequently, the quantity of air permitted to enter. An opening is to be made in each of the sides, in order that, when necessary, the air may be admitted at the side or sides most nearly facing the wind. And the chief use of having a moveable part of the shaft to stand, when raised, a certain height above deck, is, that it may catch the wind.

The colder air is to be conveyed, as above mentioned; by an enclosed passage, without permitting it to mix with the mass of warmer air already within the vessel, down to the described level, to prevent the heat of the warmer air from mixing with and rendering it specifically lighter, and thereby obstructing and stopping it in its passage; and in order, that, by so introducing it at once down below

the body of warmer air, it may, by its greater weight, and the weight of the column of the like air within the shaft, push the warmer up before it, and, through the apertures to be provided for the purpose, out of the vessel; and that, on becoming warmed, it may be itself pushed up and out in its turn; and that, thus, a continued circulation of colder air, and passing off of heat, may be kept up, as occasion requires.

But, merely to introduce the colder air down to the required level in midships, would not serve to pass off heat with sufficient quickness from the parts situated near either end of the vessel. In some cases it might also do mischief, to introduce the whole quantity of colder air, required for passing off heat from the different parts of the vessel, into the lower parts at midships, and allow it to mix with the mass or body of air there. For conveying the colder air, therefore, more immediately to the parts from which the passing off of heat is required, a hollow trunk of timber or such other materials as already mentioned, is to be attached to each side of the shaft fore and aft, and is to reach from thence, in as straight a line lengthwise the ship as practicable, and preserving the same level above or distance from the kelson, a sufficient length to convey the air to each end of the vessel, as may be required. And for distributing the air in the intervening parts, where needed, each trunk is to be provided with different orifices for it to issue from, situated at convenient distances from each other for the intended purpose. And, if necessary, by reason of there

being any separate rooms or enclosed places in the interior into which the leading trunk does not enter, one or more lateral trunks are to be attached to it to reach into such rooms at their lower parts, in order that the colder air, when necessary, may be conveyed into every separate room.

But the supply of air is to be a regulated or measured quantity or supply, as well for each particular part at which any is needed, as for the whole interior generally. To effect this, the trunks are to be provided with a sliding hatch, or other such contrivance, to be placed near each orifice, between the orifice and the hollow shaft, for regulating at pleasure the size of the opening for the passage of the air; and, consequently, the quantity of air permitted to pass.

But again, the temperature, as well of the interior of the vessels, as of the outer air and water, being liable to be different at different depths, it will, in the larger classes of vessels, for the more perfect and thorough application of the remedy, be necessary to be provided with the means of introducing and distributing the colder air at more than one depth or level in the interior. For instance, supposing the outer air to become at night, or on a change of wind, considerably colder than the water, it would be desirable, and, towards the most perfect application and putting in practice of the invention, necessary, to be furnished with the means of introducing the air only down to a little above the level of the water line, and to guard, as far as practicable, by limiting the quantity admitted, against permitting

any considerable portion of it to descend below that line. And the importance of this will be in proportion to the vessel's draught of water. It is, however, to be observed, that supposing colder air to be introduced into the upper part of a vessel, the complete prevention of the descent of any portion of it below the level of the water line could only be effected by cutting off, by some material impervious to air, all communication with the parts lower down. But resorting to such means for precisely regulating the introduction of colder air down to a particular depth, might indirectly even do more harm than good; and the object of protecting the timber from the passage of the heat may be sufficiently attained without it. Besides, the water itself will be of different temperatures at different depths, and it therefore might not, in the case supposed, be the very thing required, to introduce colder air precisely down to the level of the water line without any part of it descending lower. And hence it may be seen that the nature of the subject will, at once, only either require, or admit of, our fixing on a kind of average depth to which to introduce, and at which to distribute, the colder air, and our striking a kind of compromise of approximation of temperatures at the opposite sides of the timber at different parts of the vessel, in particular cases that may arise.

For effecting the general object of distributing colder air at more than one level, in vessels of such a size, or engaged in such a trade, as, whether from their depth alone, or the heating nature of their

cargoes, or the liability of the climate to great and sudden changes of temperature, or from these causes combined, to render it necessary or advisable, an additional set of trunks is to be attached to the hollow shaft, fore and aft, at a certain height above the former, and is to extend from the shaft towards each end of the vessel in like manner as the former; and to be provided, of course, with the like orifices and sliding hatches. And, in general, the best height or level at which to place them will be midway between the lower trunks and the underside of the deck. If the vessel have more decks than one, there should be an additional set or main of trunks for the introduction of the colder air to each place between decks.

The providing, however, of the several things, or apparatus, that I have been mentioning, will not alone ensure the regular entrance of a current of colder air, and passing of it off when heated, with the excess of heat from the interior, even when the temperature within is so much higher than at the outside as to call for such a circulation and change of air, and passing off of heat; and even supposing the colder air to be, in fact, heavier than the hotter, as, ceteris paribus, it will be. There is no law of nature by which the colder outer air would always enter at the shaft in preference to entering at one or more of the apertures intended for the hotter air within to pass off at, nor any law to prevent it from partially descending through each aperture, and receiving a part of the heat from the hotter air situated immediately below each, and being thereupon put

into a kind of to and fro motion, and caused partially to reascend till the newly received heat has again parted from it. And all this would evidently be incompatible with there being any regular current of air passing through the interior, and carrying off the excess of heat along with it. And although the circumstance of the apertures in the deck intended for the passing off of the heated air, and the apertures in the moveable part of the shaft above deck being at different levels, would, in case of an excess of heat in the interior, tend, commonly, to the creating of a current of air in the one direction or the other, yet it would not uniformly take place or continue in the same direction; but, according as it happened that the column of air within the shaft was hotter or colder than the column of air between the same levels, in the interior, and at the outside, below and over any of the other apertures, the current would take place up the shaft, or down it. And if it took place up the shaft, it could not regularly pass off heated air from the under side of any parts of the deck situated at a distance from the apertures through which the colder air entered; because the latter, in such case, on entering, instead of regularly dispersing or distributing itself in immediate contact with the underside of the deck, where the hotter air would principally be, would, from its greater weight, have a tendency to immediately descend down to, and to enter, the orifices in the trunks attached to the lower part of the shaft; while the hotter air, for the most part, would still remain at the underside of the deck. And hence, too, no continued current

of air could take place up the shaft, for want of the air supplied generally mixing with, and becoming heated by, the hotter air, and carrying the latter down with it to the orifices in the trunks; but the current would be liable to take the opposite direction every instant; thus bringing back again a portion of the air that had made part of its way out, and thereby, one minute, undoing what had been done the minute before.

To prevent the regular passing off of heat from being thus defeated, I have invented a new kind of valve, that will permit the air to pass in the direction required, and prevent it from returning. The principle of this invention consists in making the working part of the valve of some light and elastic substance, so flexible as that it will readily yield to a slight pressure of air, and so attaching and placing it over an aperture through which the air is to pass, as that it will yield accordingly, and permit the air to pass through, and will immediately resume its former position, or shut, on the ceasing of the pressure, and prevent any air from passing in the contrary direction. The effect, therefore, of this valve will be to ensure any current of air, that takes place, taking place in the right direction; and to prevent what is already done from being undone. And, in both these respects, its use will be closely analogous to that of the valves in our veins.

The lighter, the more flexible, elastic, and strong, and the less liable the material may be to absorb much moisture, the better. And although, with persons unacquainted with the property of size to

absorb little moisture from the air, the mention of the substance which I consider as possessing the above mentioned qualities combined in a higher degree than any other that I am aware of, has more than once been received with marks of dissent as to its efficacy, the best material to be made use of, in my judgment, will be thin superfine writing paper. And I have been fully confirmed in this opinion by an experiment, which, in consequence of my very mention of such a material having appeared ridiculous to some of my uninformed learned friends, I made, by putting nine pieces of four sorts of writing or printing paper into a pail of water. I put in four of the pieces flat, and the other five with the edges turned up, from about a quarter to about half an inch, and turned round at the corners, so as to form little oblong, or square, shallow dishes. It would take up too much room to detail the particulars; but finding that none of the pieces sunk, or appeared likely to sink, I put half-pence into those, the sides of which were turned up. The results were, that the water did not, in any instance, come through the paper; and that one of the pieces, the bottom of which was only about three inches square, supported three half-pence on the water five days; and another piece, scarcely as broad again as the half-penny itself, and not turned up above a quarter of an inch, supported a half-penny six days, before it sunk. And the way in which they were finally sunk was, by the paper being gradually deepened in the water, by the weight of the half-pence, into the shape of a purse, till the water, after standing a whole day above the

edge where it was lowest, as it is sometimes seen standing above the edge of a tea cup, at length ran over into the purse; when, of course, the paper with the half-pence instantly sunk. The flat pieces, which were not loaded with half-pence, did not sink at all; and those which did sink, on being taken out of the water and dried, did not appear to have been materially injured in their texture.

These valves are to be placed in the two following situations: first, in the orifices of the trunks, to prevent any air that has once issued from the trunks, from returning into them; and, secondly, in the discharging apertures for the passing off of the heated air, to prevent any colder air from there entering the vessel, and to preserve the interior free from any such, till the air within has been rendered lighter, by the heat, to a sufficient degree for the column of colder air in the shaft to enter through the trunks and their orifices, and open the valves, and push the warmer air before it, up through the discharging apertures and valves, out of the vessel.

The valves, it is to be understood, will have no tendency to cause a circulation of air, any more than the valves in our veins to cause a circulation of blood; but, on the contrary, in proportion to the force required to make their working material yield, or, in other words, to make them open, they will oppose resistance to and lessne any current of air, and they will prevent any current from taking place where the force is not sufficient to overcome the resistance. Hence the advisability of making them of as thin light and flexible a material as can

be found, provided it have sufficient elasticity to quickly resume its first shape and position on the ceasing of the pressure, and sufficient strength to resist, without being torn, sudden gusts of wind. The sum of the moving force will, commonly, be the difference between the weight of the column of colder air in the shaft between the level of the orifice in the trunk at which it issues into the interior, and the level of the deck, and the weight of the column of hotter air in the interior above the level of the same orifice. Supposing the orifice in the trunk, indeed, not to be quite at the bottom of the hotter air, the force will be somewhat greater; because the colder air, on issuing from the orifice, will have a tendency to fall to the bottom, and in so far as this tendency is not counteracted by its receiving a part of the heat from the hotter air below, through which it will have to fall, the force will be augmented in proportion to the increase of depth of the column of colder air. And, ceteris paribus, as has been stated, colder air is, and will be found, heavier than hotter; insomuch that, with a difference of a few degrees of temperature on the thermometer, it will set the valves working. I have, this summer, (1828,) seen one of my valves sensibly working, by letting out the colder air from my vault, with a difference of temperature of only three degrees on the thermometer. I ought to state, however, that the paper used was what is called tissue or silver paper; which, I should suppose, will scarcely ever be found sufficiently elastic and strong on board ship, except, perhaps, in situations

low down in the interior, where it cannot be much exposed to violent and sudden gusts of wind.

But it is only ceteris paribus that colder air is heavier than hotter. For the latter may be charged with such a quantity of moisture as to make a cubic foot, or other given volume, of it, as heavy, or heavier, than an equal volume of other air some degrees colder. It is its being thus loaded with moisture, and rendered specifically heavier, that causes it so frequently to make the dust fly in such dense clouds just before the coming on of a heavy shower of rain in summer time. When the hotter air within a vessel is, from its being thus charged with moisture, or from any other possible cause, heavier than, or of too nearly equal weight with, the colder air, for the latter to open the valves, the apparatus, which I have been describing, will not serve to pass off the excess of heat from the interior; and, on this account, it may be remarked, that I have only described it as being for the introduction, in general, of the colder air, for passing off heat. And when the supposed cases, in which it will not answer the intended purpose, occur, the hotter air is to be removed from the vessel by the means which I have provided, and which will presently be described, of removing colder, for causing the entrance of warmer, air, when the introduction of heat is required.

But again; besides providing the apparatus already mentioned for the introduction of colder air for passing off any excess of heat, it is desirable that means should be taken for ensuring its pretty

regular and equable discharge when heated, and for protecting it from being much exposed to be blown back on the valves, and, at the same time, protecting such of the latter as are situated in the discharging apertures, from the rain or other wet. To effect these objects, chimnies, with their lower parts, or shaft, composed of timber, or some other material little pervious to heat, and with covered tops, (which will be best if of metal), are to be placed over and round the discharging apertures and valves, and are to reach a sufficient height above deck to discharge the heated air at a level a little above the bulwarks; near to which, the apertures will, for the most part, be situated. The tops of the chimnies may either be fixed, or be constructed so as to revolve with the wind. But, in either case, they are to be made with sides sloping, on the inside, from the apex or centre of the top, so as for any water, that may be lodged against their inner surface, to trickle down the sides, and fall on the deck, or into any receptacle to be put there for it on the outside of the chimney; instead of suffering it to drop on the valve, or run down within the chimney. Water, it may be observed, will often be lodged against the inner side of the chimney-top, in consequence of heat leaving the hotter air in contact with it, to pass out through the metal into the colder air, and of the air within being unable to hold suspended in it the same quantity of moisture after losing a part of its heat.

If the chimney top be fixed, its internal dia-

meter is to be so much larger than the outer diameter of the body of the chimney, as to leave a sufficient space between them all round for the passing off of the heated air. And its lower edge, or rim, should descend a little below the top of the body, or shaft, to diminish the force of any occasional blowing back of the air upon the valve. But this, perhaps, will better be prevented by constructing the top so as for it to revolve with the wind. And, in this case, in order to cause it to revolve freely in every position of the vessel, it is to be constructed so as for its centre of gravity to be in the centre, and equidistant from the ends, of the axis round which it revolves. I have had a chimney top of this kind made of common tinned iron; and although it is not made quite true, but has some play on its axis, it remains sufficiently at rest, in however slanting a position, and in whatever direction it is turned, to have established the truth of the principle on which it is constructed, to the surprise of my furnishing ironmonger, who denied that the proposed object could be accomplished, because, as he stated, neither a chimney-cowl, nor a smoke-jack, would act if out of the perpendicular. When a revolving top is made use of, its internal diameter need only be so much larger than the outer diameter of the lower part, as is requisite to leave sufficient room for the water to trickle down between them, without touching the latter. And it will be best to construct these revolving tops so as for them to discharge the air horizontally, when the vessel is upright. A repre-

sentation of both kinds of chimney top will be found among the drawings at the end of the book.

Cock-roaches, or other insects, or vermin, that will consume paper, or, as I am told, almost any thing else, being liable to be found on board ship, I have considered it necessary, more particularly for long voyages, to provide the means of always getting at the admitting valves that will be situated at a depth below goods, in order to renew the paper, or other light working material of the valve, in case of its being destroyed in the course of the voyage. And as, in merchant vessels, it is the common practice to stow the goods close up to the underside of the deck, I have provided, for this purpose, an open lattice work to surround the valve, and to be of a sufficient diameter for passing it up and down within it, to reach up to the deck, through an aperture in which the valve is to be passed. The aperture is to be furnished with a proper coaming and cap scuttle, for commonly keeping it closed. The lattice work must, of course, according to the particular description of cargo, be made of a strength adequate to resist the pressure of the goods. And in the same lattice work, and reaching up through the aperture in the deck and the cap scuttle, is to be a thin rod of metal or wood attached at its lower extremity to the sliding hatch in the trunk for regulating the size of the passage for the air, and furnished at the upper side of the cap scuttle with the means of keeping it raised or lowered to any required ex-

tent. And for letting down or taking up the valve, I have contrived a jointed folding rod, somewhat like a carpenter's rule, to be made of wood with metal hinges, and to be in convenient lengths between the joints for using it in low places between decks, and furnished with a hook at its lower end for hitching into an eye to be made in a handle or thumb piece of the valve. Representations of the last described parts of my apparatus will likewise be found among the drawings.

To permit the air to circulate freely from one part of the interior to another, and, more especially, for passing off heat from among goods liable to sustain damage by heating, where the shape of the packages is such as not to leave sufficient interstices for the passage of the air between them, rectangular battens perforated with holes are to be provided, and are to be placed under and between the different layers or tiers of packages, sufficiently near together to preserve a small passage for the air between each tier. And to avoid damaging the goods by the pressure, the battens should be rather flat, as, for instance, with two of their sides not less than twice as wide as the two others; and the holes should be perforated through the two narrower sides. It is, commonly, the packing of goods, liable to damage on board ship by heat, in packages too large, or the loading them in bulk, and the want of means of carrying away the heat from them by a circulation of air, as the heat is generated, that, together, cause it to attain such an intensity as to damage or spoil

the commodity. For goods contained in casks of a moderate size, or other packages of a circular form, or of any other shape that will leave interstices for the passage of the air between them, no such contrivance as the perforated battens will be needed.

Thermometers, as already mentioned, being to be made use of for ascertaining the temperatures on the opposite sides of the timber, in order to know when to introduce, and pass off, either warmer or colder air, into and from any particular parts of the interior; a sufficient number of them are to be provided for placing a thermometer at each side of the timber, both within the vessel, and at the outside, where practicable, in as many situations as, from their distance from each other, or for any other cause, any material differences of temperature are liable to be found at. According to this principle of arranging the thermometers, the most proper disposition of those in the interior will be to place them at two or more levels, one thermometer below another, against the ends and sides of the vessel, and also occasionally in the lattice works before described, where the vessel is provided with lattice works. The best situation for the lower thermometers will be at about the level of the heads of the floor timbers in midships, and of the kelson at each end; and the upper ones should be placed immediately under the deck; and any intermediate row, which the greater depth of the vessel, or the heating nature of the cargo may render expedient, may advantageously be placed about midway between the former. And I

recommend that the distances of the thermometers from each other, lengthwise the vessel, be from thirty to forty feet, and the depths between them not exceeding from eight to ten feet. For letting down the thermometers to the required levels in loaded ships, I have contrived narrow grooves, open in front, to pass them up and down in, free from obstruction by the goods. The thermometers at the outside of the vessel are to be placed as nearly as practicable immediately opposite those situated within; and all thermometers to be placed at the outside, are to be protected from the direct action of the sun's rays. It would, on various accounts, be objectionable to keep thermometers placed below water at the outside of a vessel. And, therefore, for ascertaining, when necessary, the temperature of the water at the different depths corresponding with the levels at which the thermometers below the level of the water line are placed in the inside, the best means in use for that purpose are to be had recourse to. Representations of the thermometers in the situations proposed, with the grooves for letting them down, and the guards to protect them from the sun's rays, may also be seen among the drawings at the end of the book. These guards, I may observe, may in a tropical sun require a cover to be placed at some distance above them to prevent the sun from shining down on the thermometer, and to leave, at the same time, sufficient room for the air freely to pass up and down.

I have before described all the apparatus and

88510

machinery which are more particularly provided for the introduction, in general, of colder air into the interior of a vessel, and passing it off again, when heated, with any excess of heat along with it. When this apparatus will not act, or it is thought not to act with sufficient quickness, the colder air is to be introduced and passed off, as long as may be necessary, by the means next described, which I have invented principally for removing heavy gases that may collect in the lower parts of the interior, and, if not removed, prevent the above described entrance and circulation of colder air, and passing off of heat, and for causing the entrance of warmer air when the introduction of heat is required.

CHAPTER IX.

The description of the invention concluded. Warmer air introduced by removing the colder, and means provided of introducing it at pleasure, to particular parts, and levels only, and in regulated quantities to each level. A descending hollow trunk furnished with apertures at different depths, with the means of closing them completely or to any partial extent. The colder air to be removed up through the trunk by any adequate means; as, a pump, &c. The air removed discharged where. The pump, &c. to be sufficiently large for the removal of colder air to keep pace with what. A hose attached to each side of the descending trunk, fore and aft, for what purpose. What to be done on introducing warmer air. General rules on introducing and passing off air, whether colder or warmer. When to keep the temperature of the interior a little the higher, and why. The air within to be kept as dry as practicable, and why. Subject to what precaution, the interior, for the comfort of the persons on board, may be kept of considerably the higher temperature. By means of one part or the other of the invention, the outer air, whether colder or warmer, (the safety of the vessel permitting,) may always be introduced and passed off again in any required quantity, to and from any parts where required. And by means of it, the desired approximation of temperatures may, in general, be maintained. One exception only known to the author, and in it the complete attainment of the object sought, an impossibility. But in the excepted case, the force of the current of heat may be mitigated and divided among different pieces of timber in succession, and be rendered little hurtful. The invention, however, on this account, only represented as

having the limited power of attaining the proposed objects, as often and as far as practicable by the means used. But these means more effectual than any others.

When warmer air is required to be introduced into the interior of a vessel, from its being specifically lighter than colder air, and being therefore unable to descend by its own weight into the interior and displace the colder air already there, its introduction is to be effected by taking separate and distinct means of removing the colder air out of the vessel, and thereby making room for, and causing the warmer to enter and take its place.

But as the outer air and water will, most commonly, be of different temperatures at different heights or depths and levels, it may, as has already been stated, and will, in general, be requisite and proper to introduce as well warmer as colder air down only to certain depths in the interior, and to introduce it in different quantities to the different depths. Thus, every forenoon, in a hot climate, as the sun advances in the sky, and heats the outer air and the outside of the vessel, it will in general be necessary to introduce such a quantity of the warmed air into the interior, as will serve to cause a correspondent rise of temperature there. But it will be proper to introduce it, in what may be called full supply, only down to about the level of the water line, below which the action of the sun will have less effect; and to raise the temperature at different depths below the water line, only in the lesser degrees in which the sun raises the temperature of the water at the same depths, down to

the lowest to which it sensibly affects it. It may also, sometimes, be necessary to introduce the warmer air only into particular parts lengthwise the vessel, whether in midships, or at or near either or both ends.

The apparatus which I have contrived for thus introducing the warmer outer air in different quantities down to different depths or levels in the interior at pleasure, is an upright square hollow trunk to be situated as near the middle of the vessel as practicable, and placed so as to descend straight down to near the bottom of the hold, and provided, at so many different depths or levels as any material differences of temperature are liable to be found at, with apertures furnished with doors or sliding hatches for opening and closing the same at pleasure; by opening any one or more of which and closing the others, the colder air which is to be removed will be received at any desired apertures, and by opening or raising the door or hatch of any particular aperture, to a greater or lesser extent, the quantity of air admitted through it will be regulated; and, consequently, also the quantity of warmer outer air which will be introduced down to the level of such aperture for supplying the place of the colder air that is removed. This trunk, with its apertures, and their doors or hatches, being provided, the colder or heavy air may be removed up through it by any adequate apparatus to be attached to, and to communicate internally with it above the level of the uppermost of the apertures just described. It may be removed, first,

by a pump; secondly, by a machine differing in principle from common bellows, only in having a larger aperture for the discharge of the air than for receiving it, in order to its easy discharge, instead of requiring considerable force to expel it as is the case with the common nozzle of a pair of bellows; and thirdly, in all cases except where the air or gas to be removed is such as will not support combustion, by a stove constructed so as to receive all the air for the supply of the fire through a pipe made to communicate with the trunk as above mentioned. The pump, or other machine to be made use of, ought to be of large dimensions, in order to remove the air sufficiently fast for the increase of temperature in the interior by the entrance of the warmer air, after allowing the difference of temperatures, which is still to remain between the inside and the outside of the vessel, to keep pace with the increase of temperature of the outer air and water. In my legal instrument of specification, I have not thought it advisable to recommend for a vessel of four hundred tons burthen, trading in temperate latitudes, smaller internal dimensions for that part of the pump in which the piston is to work, and which I have called the piston box, than about a cube of four feet, so as to pump up at each stroke about sixty four cubic feet of air. But a pump of such a size, in such a sized vessel, will, I apprehend, do its work with sufficient quickness to require being worked only a short time at each spell or turn. And supposing a stove to be made use of, as its action, on a fire being lighted, would be continued

as long as the fire was kept up, and be in proportion to the briskness of the fire, without requiring any exertion of animal strength, the pipe from it communicating with the descending trunk may be made of a bore considerably smaller than the hollow of the latter. Where the area of the piston box is four feet square, I recommend making the area of the hollow of the trunk about one foot square, or a sixteenth part as large as the former; although if it bear a larger proportion the labour of working the pump will be the less; and, in fixing on the exact proportion, the business will be to strike a balance, as it were, between the disadvantage in the loss of room by increasing the size of the trunk, and the advantage in the saving of labour, by so doing, in working the pump.

The descending trunk will, of course, most readily introduce the warmer air into midships. But for more quickly introducing it, when needful, at or near either end of the vessel, the trunk is provided with another aperture and door or hatch in each side, fore and aft, situated at about the mid-height of the interior. To each of these apertures is to be attached a hose of stout leather, or other sufficiently stiff material, extending a considerable length towards each end, and so as to receive the colder air at parts sufficiently near each end to draw it from thence without the necessity of first removing the air in midships.

On introducing warmer air, the valves are, in general, to be taken out of the discharging apertures for heated air, which communicate more imme-

diately with those parts of the interior in which the warmer air is required, and the warmer air is to be admitted through such apertures. And for its more regular distribution immediately underneath the planks of the deck, and in the upper parts of the interior, where it will commonly first be required, the other entrances into the interior should, during its admission, commonly be kept closed. But where the warmer air is required in the very lower parts, as, for instance, where a vessel suddenly enters the gulf stream, or any water materially warmer than before, it may be permitted to enter through the hollow shaft and the trunks for the admission in general of colder air, as well as through the other entrances.

The alterations in the vessels and the apparatus and machinery being made and provided, observations of the temperatures are to be taken with the thermometers as often as any material change is liable to take place. And on introducing and passing off the outer air, whether colder or warmer than that already within the vessel, a few general rules are to be observed, in regulating the quantity of it to be introduced.

First: it should be made a general rule to keep the temperature of the interior, where practicable, a little higher than that at the outside, where the outer air is charged with any considerable quantity of moisture, or where the particular part of the interior is situated below the water line. While the temperature within is the higher, we are sure that no heat can be working its way through the

timber inwards; which it otherwise will do, in the cases supposed, with comparatively small differences of temperature.

Secondly: the air of the interior should be kept as dry as practicable. The drier air is, the less quickly will heat leave it to penetrate a substance of lower temperature, and, consequently, a greater difference may be permitted between the temperature within and that at the outside, where the temperature within is the higher, without endangering heat's passing through the timber.

Thirdly: the more moisture there is contained in the outer air, the smaller a quantity of it will be required for passing off a given quantity of heat. And, on account of the greater rapidity with which heat enters or leaves air much charged with moisture, on introducing any such air for passing off heat, the greater caution should be used not to introduce more of it than is necessary. But it should be studied to admit, as nearly as practicable, just the requisite quantity for passing off the heat, without permitting the air with the excess of heat in it to remain lodged against the upper parts of the interior, for want of a continued supply of other air to force it up and out before it.

Fourthly: provided there be the requisite supply of new air to preserve a continued circulation and change through any particular part of the interior, and such air be moderately dry, the temperature of such part may, if desirable for the comfort of the persons on board, be kept a considerable number of degrees higher than at the outside of

the same part, without causing any heat to pass through the timber, or if any, at least not any such considerable current of heat as would work its early decay. But without such a supply and change of air in the interior of any vessel having a number of persons on board, the heat generated by them, and the moisture of their breaths, would soon load the air with a sufficient quantity of both heat and moisture to cause the excess of the former to force its way in a hurtful current or stream through the timber, with comparatively small differences of temperatures on its opposite sides.

" It is only necessary for a person to understand the alterations in the vessels and the apparatus and machinery which I have now generally described, in order to see, that, except when the weather will not admit of the several apertures for the entrance and passing off of the air being kept open consistently with the safety of the vessel, it is matter of absolute certainty that by using one part or another of my invention, the outer air, whether colder or warmer than that within the vessel, may be introduced and passed off again, in any required quantity, to and from any parts where required. And it is only on comparatively rare occasions that can still more rarely be of lengthened continuance, that a sufficiently near approximation of temperatures on the opposite sides of the timber for the object in view, cannot be maintained by the introduction and passing off again of the outer air. The only case, indeed, that immediately occurs to me in which such an approximation of temperatures cannot be

maintained by the means provided, (nor, I may add, by any other means,) is where the water happens to be very materially warmer than the air. And this may and will be more or less the case in a severe frost; but more so at first, while the body of the water may still be a considerable number of degrees above the freezing point. In this case, a current of heat, more or less considerable, according to circumstances, may leave the water below the vessel to pass up through the bottom inwards; and supposing the colder air were freely admitted down to the bottom on the inside, the current of heat that might so pass, might be very considerable. But the force of the current, in such case, may be mitigated by taking care not to admit into the interior any more of the colder air than what may be required for carrying off moisture, and keeping the air within comparatively dry, and to keep the general average temperature of the interior as high as practicable, consistently with so carrying off moisture. For although, by so doing, the deck and upper works will be exposed to the passage of more or less heat through them, the heat which so passes can only be that which works its way up through the bottom, and the quantity of this will be the less in proportion to the diminishing of the difference of the temperatures at the opposite sides of the bottom by so keeping up the temperature within. And, thus, the total action of the heat on the timber will both be lessened, and be shared between at least two separate structures or partitions of timber, namely, the bottom of the vessel and the deck, instead of its

full force being exerted on one only; and it will be shared between three or more, in vessels having more than one deck. And hence, even in a severe frost, the passage of the heat may be so diminished, and the sum total of its action so divided or shared between different parts of the vessel in succession, as to render it nearly or quite harmless to the several parts through which it passes.

When the converse of the case which I have been supposing takes place, namely, when the outer air is materially warmer than the water, there is no danger of the heat passing through the timber below the water line out of the vessel in any hurtful current or quantity, because the hotter air being, ceteris paribus, lighter than the colder, the former cannot displace the latter, but will remain above it in the upper parts of the vessel, and the heat will very slowly indeed make its way down through the colder air to come into the same level with the parts of the vessel below the water line, in order to make its way out through them into the water. And the heat that will make its way downwards through the timber itself across the grain of the wood from plank to plank, or with the grain down through *the timbers* (or ribs) of the vessel, will likewise be insufficient in quantity to subject the timber to early decay. For it is to be kept in mind, that it is not every passage of heat through timber that works the mischief, but the passage of a more or less rapid or considerable current of it.

There being, however, in the case above supposed of the water being materially warmer than the air,

a case in which it is out of our power to preserve a sufficiently near approximation of temperatures on the opposite sides of the timber to an equilibrium, to prevent the possibility of the occasional passage of some considerable current of heat through some part of the timber of the vessel, I have, in my legal instrument of specification of my invention, refrained from assigning to it the power of at all times preventing the passage of heat through the timber, and have only represented it as being intended for bringing and passing off heat into and from the interior of vessels, along with the common air of the atmosphere, as often as is practicable, and for preventing, either wholly, or as far as is practicable by the means used, the passage either of any current, or any considerable current, of heat through the timber. The means described, however, will be more effectual for the intended purpose, than any others that could be devised, and rendered practicable.

CHAPTER X.

Of the motives for putting the author's invention in practice. The necessity of providing a remedy for the evil of dry rot in shipping. The importance of this, which is the first object of the invention. Every vessel hitherto, that has perished by decay, at whatever age, has owed her decay to the same cause, which, in its swifter ravages, has of late obtained the name of dry rot. The comparative durability hitherto of timber in shipping, and in certain other situations. A second object, to be incidentally ensured by the invention, is the proper ventilation of the ship. The proper ventilation of a ship, a thing not hitherto understood. The healthfulness of a vessel a question of money to the owner. A third and a great object is the preservation of goods from damage by heat. How, in general, such damage is caused. The invention does not interfere with any of the established principles of ship building, nor affect any part of the ship on which its strength depends, except in one instance, which is to be compensated for by an additional thickness of timber. The application of the invention not expensive. The consideration of the room taken up, and the trouble of attendance. The room taken up does not exceed from $\frac{3}{4}$ to $1\frac{1}{2}$ per cent. of the interior. The attendance of one man, in general, sufficient. The questions for a ship owner to put to himself, on considering whether to adopt the invention. Encouragement to an early putting of the invention in practice.

HAVING now described the cause of dry rot, and explained the leading principles and the principal component parts of my invention for preserving decked shipping from the evil, and preserving goods on board ship from damage from the same source;

I shall next suggest, for the reader's consideration, a few arguments on the motives or inducements for putting my invention in practice.

The cause of dry rot being known to be such as it is, it is surely needless to insist at any length on the necessity of providing a remedy for the evil. It is evident, from what has been stated, that timber, and consequently any vessel having timber for its materials, is as much an organised thing, subject to causes of premature decay, as a living animal. So sure a cause of premature decay is it, to permit, when it can be helped, the passage of a flood or tide of heat through the timber of a vessel, instead of introducing or carrying it off by a circulation and change of air, that it might as rationally be expected to stop the mouth and nostrils of a human being and not cause his death, as to keep a vessel closed, or to fill up the interior with a solid mass without providing passages and other means of causing the circulation of the air for so bringing or carrying off heat, as occasion requires, and not expect it speedily to decay. In a word, every ship at present is like an animal without lungs, or a fish without gills; and when it is, occasionally, by the use of what are called wind sails, furnished with a substitute for what it ought to be always provided with, there still, even when the wind sails will act, are wanting, among other things, the means as well of ascertaining when and what quantity of air ought to be introduced, as of regulating the quantity admitted. And these means cannot be supplied without having recourse to more than one part of my invention, namely, to

the use of thermometers for the former objects, and to regulating the size of the apertures for the passage of the air for the latter; not to mention the necessity there is, of having also means of conveying the air along in the interior to the particular parts where it is required, and of keeping the current in the right direction.

What then is the extent of the object sought to be attained in preserving vessels from dry rot? In the predicament in which all vessels have hitherto been, it is not merely that this or that vessel, which, otherwise, from the inferior quality of her materials, or from the trade she is engaged in, would perish in four or five, or, if of superior materials, in, perhaps, ten or twelve years, is to have her duration prolonged probably three or four fold, possibly ten fold; and this, at much less expense of repairs in the meantime; but that every vessel, that has ever existed hitherto, and that has finally perished by the decay of her timber, how long soever she may have lasted, and however little she may have been suspected to have had her term of existence shortened by dry rot, has, nevertheless, owed her decay to the same cause, which, in the instances of its swifter ravages, has latterly obtained the name of dry rot; and that every vessel, therefore, stands in need of protection from it. If timber in some situations, as, for instance, in the roof of a Cathedral, or of Westminster Hall, will last five hundred years, or eight hundred years; if in others, and those, too, where it is constantly in water, and, perhaps, exposed to the pressure of an enormous weight,

as in the case of timber under the piers of bridges, it is said that it will last for ever, skilfully protect it from the action of the cause of the decay in question, and I know of no impossibility why its average durability in a ship may not be made even ten times as great as it now is. It would, of course, be folly to pretend beforehand to name any given term of years, which a ship, built of this or that kind of timber, may, by judiciously protecting her from the action of the cause of dry rot, be made to last. But if she be such a vessel as will now last five years, so protect her, and no man can assign a reason of any weight, why she will not last twenty five; or if she would otherwise last twenty years, why she will not last four score or a hundred. It was recently matter of wonder, with persons experienced with shipping, that a vessel had just been broken up in the ninety fourth year of her age, and that a great part of her timbers, and, I believe, even her tree-nails were found sound. The wonder with the inexperienced, and with all who first hear of particular instances of the rapid decay of a vessel by dry rot, is, (and it is, perhaps, the more rational ground of wonder,) that solid oak, of such immense scantling as it is in some parts of the larger classes of vessels, should be so almost uniformly doomed, on becoming a part of a ship, to such swift destruction as experience shows it to be. Now, however, that I have discovered and unfolded the cause of the decay, the wonder in each case will cease; and although it would be quackery to pretend to name any given term of

years that this or that vessel may be made to last, by protecting it from the cause of the decay, it will not, perhaps, in future times, after my remedy has been sufficiently long in practice, be matter of much surprise, when a vessel is found to have lasted a hundred years.

A second object, which my invention will incidentally ensure, is a proper ventilation of the interior of the vessel, with the view to its improved healthfulness to the persons on board. And the proper ventilation of a ship, with this view, is what has never hitherto been rightly understood.

The authors of schemes for ventilating ships have commonly proposed to introduce the greatest quantity of air possible into them; which, if it were effected, must be prejudicial to the health of the ship's company, as well as, in some cases, from what has been stated, it evidently must be to the vessel itself. Nature did not design us to be always living in squalls or draughts of wind, or in air overcharged with moisture, to which the unmeasured introduction of air into the interior of a vessel would subject the persons on board. At any rate it has never hitherto been thought of, to introduce a regulated supply of air into a vessel, such as is to be the case by means of my invention; by a judicious use of which, the air of the lower deck of a man of war may, I conceive, be kept nearly as pure as that of our breakfast parlours. By properly regulating the drawing out of the hatches, a gradual circulation and change of air may be kept up in every part where needed, without there being any sensible draught

to the persons on board. Such a circulation as that I mean, is going on in all our rooms having fire places in them in summer time, when there is no fire in the grate; as will be instantly perceived by putting a lighted candle into the chimney. The draught up the chimney, although in general none is perceived by the persons in the room, is sometimes such that, as my ironmonger has told me, on any job requiring to be done within the chimney, the difficulty is to keep the candle from being blown out.

Now the improvement of the healthfulness of a vessel ought, if only for the sake of the persons on board, to be a consideration of some weight with ship owners and persons in authority. But the loss of men by death, or their being rendered unable to do their duty, or rendered less effective in its discharge, by sickness, is also, from the necessity there is of providing a greater number of men in order to be prepared against such casualties, a loss of money to the employer. And with vessels in some trades, or on some stations, for instance, on the coast of Africa, the loss from these causes is even an important item of expense. A king's steam vessel, after an absence from England of two years, lately returned from the coast of Africa with only one white man on board besides the captain: so, at least, I was told, the captain alleged as an excuse for the dirty state of his vessel on her return. A merchant vessel trading to Sierra Leone for timber, and waiting there the necessary period of time for receiving her cargo on board, commonly loses her master, or mate, during the voyage, and

not very improbably both of them. Although a ship owner, therefore, cared little for his ship's company for their sakes, still the healthfulness of the ship is a question of money to the owner.

But there is another and a great object proposed to be attained by my invention, in preserving goods on board ship from damage by heat. And although this is an object which did not occur to me at first, it has, as I have already remarked, risen, in my estimation, in importance, every time my attention has been turned to it; insomuch that I now look upon it as being of as great consequence as the preservation of the ship itself from dry rot. In fact, inasmuch as the damage done to the goods is in each case done during a single voyage, and it may, in some instances, amount to a complete spoiling of almost the whole cargo, and the aggregate value of the cargoes in a few voyages must far exceed the value of the ship, the preservation of the goods may be of even greater pecuniary importance than that of the vessel. Among the kinds of cargoes that my own partial acquaintance with these matters enables me to instance, as liable to be damaged or spoiled by heat, are corn, fruit, flour, seed, hemp, flax, cotton, hides, and skins. Some of these goods are indeed so liable to spoil, that they cannot be sent on any voyage of a considerable length; or, if it is ventured to send them, as, for instance, apples from New York to London, four fifths of them are almost sure to be spoiled by the time they arrive. Now all these commodities, and, I presume, many others, are liable, during the voyage, to generate heat in

larger or smaller quantities, with or without moisture; or, as it is commonly termed, they are liable to heat and ferment. And the damage is done, in such cases, for want of passages for the circulation of air among the goods, and the want of proper means of keeping up a current of air among them for carrying off the heat, or the heat and moisture, as they are generated. The consequence of this is, that the heat attains such a concentration or intensity, as to cause a greater quantity of it, than otherwise would, to quit its latent state, and to be disengaged from the goods, and such a quantity as to decompose, or more or less injure the organization of the commodity itself. And this effect is produced, for want of the means of passing off the heat as it is generated, just in the same way as the scorching of the middle parts of a hayrick, from heating, takes place. Unless the heating in a hayrick be very unusually great, it is only the middle parts of it that become blackened; the heat being able to pass out, from the more outward and less compact parts, sufficiently fast to prevent the burning. The remedy for this evil, as respects goods on board ship, therefore, besides observing the precaution of packing the goods in smaller packages than is oftentimes done, and refraining from loading the kinds of goods in question in bulk, is to provide such passages for the air and heat, and such means of keeping up a current of air among the goods for carrying off the excess of heat, as have been before described.

These being the objects of my invention, it re-

mains to inquire what will be its expense compared with the value and importance of the ends to be attained, and what objections, if any, unconnected with the question of expense, can be urged against making the required alterations in the vessels, and setting up on board ship the apparatus and machinery that have been described.

With respect to objections unconnected with the question of expense, I am aware of none. The invention does not, in any manner, interfere with the principles on which vessels for the purposes of navigation are constructed; nor, except in a single instance, does it touch on any part on which their strength depends. That exception is in my directing open spaces for the passage of the air to be left between the undersides of the planks of decks, and the beams, ledges, and carlings, which support them. And if these spaces are to be obtained, as in my judgment will be best, by making curved gougings to about the average depth of an inch in the upper sides of the beams and other supports of the decks, an additional depth equal to perhaps two thirds or three fourths of that of the gouging, must be given to the beam, in order to have it as strong as before. And this is the only thing I direct of an expensive nature. For with respect to the apparatus and machinery itself, common deal will serve very well, for nearly the whole of what is to consist of wood; and but little metal will be required. As for the parts for which metal is used, cast iron will serve as well as any other metal for the frames of the valves, and wrought iron for metal rods; though brass will

be most proper for thumb-pieces, with screws, to support the rods at different heights; and copper or brass will probably be cheapest, in the end, for the chimney tops (which will be exposed to the open air); and copper wire, in different lengths, will be best for letting down and drawing up the thermometers from their stations in the grooves or other places provided for them. The lattice works, which, in the drawings, look so conspicuous, and appear to take up so much room, are indispensable only in certain cases in loaded ships, to enable one to get at the valves in order to renew the paper, or other working material, in case of its being destroyed by vermin, or from any other possible cause, during the voyage. On any other than long voyages, therefore, and voyages in which the vessel is infested with cock-roaches, or other vermin that will consume the paper of the valves, the lattices may be dispensed with; except only for the height of a foot or so above the valve, to preserve a free space for it to work in. Besides, it may be possible to prepare the paper with some substance so offensive to insects that they will not touch it. This, however, I do not take upon me to affirm, or place any reliance on. With respect to the room taken up by the apparatus, and the trouble of attending to it, I am well aware that these topics afford the only arguments against putting my invention in practice, that deserve a serious answer. With respect to the trouble, the attention of one man will be at all times sufficient to ascertain the temperatures, and regulate the

admission of colder air. And for pumping out colder air, as occasion requires, the area of the hollow of the descending trunk may be made to bear such a proportion to that of the piston box, as to render working the pump, even in a 500 tons vessel, the labour of only one man. Supposing sixty four cubic feet of air to be discharged at each stroke, its weight will only be five pounds; and, by judiciously constructing the piston and piston box, and rendering them smooth by black-leading them, the friction will be trifling.

With respect to the room taken up, the absolute space occupied by the whole apparatus, lattice works included, shown in the drawing of the 500 tons ship at the end of the book, is, notwithstanding it has so conspicuous an appearance, no more than about one and a half per cent. of the whole interior; and without the lattices, it is only about the fraction of three quarters per cent. The further room to be taken up, by preserving, by means of the perforated battens or otherwise, passages for the air among the goods, is properly to be laid to the account of the particular cargo; and its extent will depend on the nature of the goods, and their liability to generate and to sustain damage from heat, and on the quantity of air required for passing off the heat as it is generated. Still there is, doubtless, room taken up both for ship and cargo. But so is room taken up by the lungs in the human body; and, I apprehend, at least ten or fifteen times the proportion of the whole interior of a vessel is occupied by the engines, the boiler, and the coal-hole,

in a steam vessel, to that which will be occupied by my invention? In a word, the questions for the owner of a merchant ship to put to himself are, is this the discovery of the true cause of dry rot, and is the author's invention the natural and proper remedy for the evil in shipping, and for effecting the other objects stated? And, if so, shall I, for the sake of the proposed objects, adopt the invention, and as the room that will be taken up is stated not to exceed from three fourths to one and a half per cent. of the absolute space of the interior, shall I be at the expense of building my vessel, perhaps three or four per cent. larger, in order to her carrying an equal cargo with a vessel that is not furnished with the invention? For ships of war, which have numerous crews, the motives for adopting the invention are still stronger than in cases of merchant ships, where no very heating cargoes are carried; and the larger the vessel, whether in ships of war, or merchant ships, the greater and the more vital is the necessity for having recourse to the proffered remedy for the evils to be guarded against.

In concluding this part of my work, I take leave to intimate, with respect to the terms on which I propose to license the use of my invention, that I shall be willing to leave to the ship owner four fifths of the advantage to be derived from it, reserving to myself the remaining fifth, to be calculated at so much per ton per annum during the term of the patent, while the vessel lasts. And as an encouragement to an immediate putting of my invention in practice, I

will permit, on certain conditions, the gratuitous use of it in three vessels of different classes; and allow to the first hundred vessels advantages according to their priority. And I may observe, that the smaller classes of vessels will be required to pay less per ton than the larger ones, both because the comparative expense of the apparatus itself will be greater in the smaller vessels, and because, although every decked vessel, which perishes by the decay of the timber composing her, owes her decay to the same cause, that, in its swifter ravages, has obtained the name of dry rot, yet, as a general rule, the larger the vessel, the more powerful and rapid is the action of the cause of the decay, and the greater, consequently, is the benefit to be derived from preserving her from it. And the same holds with respect to any heating cargo on board. The larger the cargo, the more need is there of means of preserving it from damage by heat.

CHAPTER XI.

Explanation of the Plates.

THE plates, which will be found inserted at the end of the book, contain working plans of two specimens of my invention, applied to two vessels of different sizes; with working plans of the several parts of the invention shown separately. The plates representing the invention applied to the vessels are on a scale of a quarter of an inch to a foot. The smaller of the two vessels is of 200 tons burthen, the larger of 500 tons. In the drawing of the larger vessel the invention is shown with the lattice works; the use of which, as before mentioned, is to preserve the means of getting at the valves situated at a depth below goods, in a loaded ship, during the voyage, in order to renew, when necessary, the working material of the valve. And in this drawing, the invention is shown at its greatest disadvantage as it regards the room taken up by it, inasmuch as a vessel of 800 or 1000 tons burthen will require no greater number of hollow trunks, and but few, if any, more either of lattice works, discharging apertures and chimnies, or of thermometers, with their several appendages.

The plates representing the several parts of the invention separately, show them on a scale of

three quarters of an inch to a foot, and, for greater distinctness, some of the minuter parts are again shown on a three-inch scale. The specimen of the invention thus exhibited, is the same as that in the 500 tons vessel, only it is shown on the larger scales just mentioned.

For the reader, who is wholly unacquainted with the business of ship building, it is necessary to observe, that shipwrights, on building vessels, make use of drawings called, as above, working plans. These drawings represent, on a certain scale, the outlines of the different parts of the thing which is to be built, in three different points of view. The first draught is called the half-breadth plan. In this view you look directly down upon one half of the vessel, shown as if it were cut in two in the vertical middle line running from stem to stern, and you here see the top sides of the several parts, as far as they are represented, shown placed in the different situations which they are to occupy, as well fore and aft, as crosswise the vessel, and, as far as practicable, one below another. And for exhibiting those parts which in the thing itself would be concealed from view by others being situated over them, the contrivance is resorted to of using ticked, or dotted, instead of full lines. In the second view, which is called the profile, or profile draught, you see represented, in a similar manner, that side of the several parts composing the same half of the vessel, which faces the before mentioned middle line. The third plan is called the section, and is commonly the midship section of

the vessel, looking at it from head to stern. Here the whole breadth of the ship at midships is given, with that side of the several things represented, which faces the head of the vessel. In the present case, for showing the invention with greater clearness in this point of view, two sections are exhibited; one, chiefly for showing it from the head of the vessel to about midships, including the hollow shaft for the admission of colder air; and the other, for showing the descending trunk, with a pump for introducing hotter air by removing the colder.

It is further to be explained, that, where the same part of the invention is represented in different plates, it is designated by the same figure, or figure and letter, as it happens, on each plate.

1 1 1 The hollow shaft for the admission of colder air, with its moveable part raised, and the aperture, &c., in one of its sides, with the sliding shutter or sash let about half way down.

1 *a* A rope for suspending the moveable part of the shaft to the main stay, or other adequate support.

1 *b* An air trap in the bottom of the shaft, to stop the air and permit water to drain into the well.

1 *c* The web, &c., for drawing the shaft shutter up and down, shown on a three-inch scale.

2 2 2 The hollow trunks attached to the shaft for conveying the colder air to the parts where required.

2 *a* 2 *a* Upright hollow trunks for conveying the air to parts situated under the quarterdeck and forecastle.

3 3 3 Orifices in the trunks for the issuing of the air into the interior, with (in some of them,) the newly invented valves to permit it to pass, and prevent it from returning; some of the valves being shown in action, and others at rest.

3 *a* 3 *a* Projecting boxes communicating with orifices in the side of the trunks, with circular orifices in their upper sides for receiving the admitting valves, and the issuing of the air into the interior.

3 *b* 3 *b* The valves shown separately on a three-inch scale.

3 *c* 3 *c* Wire cages placed over the valves under the quarterdeck, &c., to protect the working material from accidents.

4 4 4 Sliding hatches for regulating the size of the passage for the air to the orifices and valves, with rods, joinings in the longer rods, staples for guiding them, handles for drawing them up with, and rodings and thumbscrews for retaining them at any required heights.

5 5 5 The lattice works for long voyages, and for vessels infested with vermin, to preserve means of getting at valves situated at a

depth below goods in loaded vessels, to renew the working material of the valve during the voyage.

5*a* 5*a* The folding rod for passing the valves up and down within the lattices.

5*b* Hook of the folding rod enlarged.

5*c* 5*c* Cap-scuttles and coamings over lattices, to keep out the wet, &c.

6 6 6 Apertures, with valves, for discharging the heated air; the apertures being also for the entrance, when called for, of warmer air, on removing the valves.

6*a* 6*a* Coamings round the last mentioned apertures.

6*b* 6*b* The like apertures and coamings on the quarterdeck and forecastle, with the valves put up from the underside, and supported by bolts, &c.

7 7 7 Chimnies for passing off the heated air, composed of separate staves, with the lower ends enlarged to fit the coamings and to make room for the discharging valves to work in, and furnished with revolving tops to discharge the air in the direction of the wind.

7*a* 7*a* Clasp hoops, to be screwed closer together as the staves of the chimnies contract by dryness, and the hoops lengthen by heat, and let into notches in the staves so as to lie flush with their outer surface.

7*b* 7*b* A chimney stave separately shown.

7*c* 7*c* The revolving chimney top.

7 *d* The upright axis, or spindle, on which the chimney top revolves, with the pipe which encompasses it, and a thumbscrew passing through the pipe and projecting into a small groove cut round the spindle, to prevent the top from being blown off by the wind.

7 *e* Handles for lifting the chimney off the coaming, to put in and take out the valve.

7 *f* A fixed chimney top, to pass off the air between the chimney shaft and top, and shaped so as for water to trickle down its inner surface and drop on the outside, instead of dropping on the valve.

7 *g*, 7 *g* A metal apron fitted round these chimney shafts, and reaching below the coamings, to keep out wet.

7 *h* The upright axis, or spindle, &c., for the revolving top, on an enlarged scale.

8 8 The descending trunk for removing colder or heavy air or gases, with its apertures at different depths for receiving the air, and its sliding hatches, or doors, with rods for raising and lowering them, and rodings and thumbscrews to retain them at any required heights.

8 *a* Joinings in the longer rods.

8 *b* Clasping staples for guiding the rods.

8 *c* A staple on an enlarged scale.

8 *d* A joining enlarged.

9 9 The hoses attached to the descending trunk, for receiving colder air from parts situated towards the ends of the vessel.

9 *a* Orifice for a hose in the descending trunk.

9 *b* Mode of attaching the hoses to the shaft, on an enlarged scale.

9 *c* A hose shown separately, passed through loose hollow trunks, to protect it, where necessary, from pressure by goods.

10 10 A pump communicating with the descending trunk for pumping out cold and heavy air.

10 *a* The lower part of the piston box of the pump, with light valves, like common bellows or pump valves, shown, in the profile and section, in action.

10 *b* A lateral trunk communicating with the descending trunk and the piston box, for conveying the air to the pump.

10 *c* The piston itself of the pump, with the like valves, as last mentioned, at rest. The edges of the piston provided with leather, &c., on the top, to make it more air tight. The sides of the piston box to be quite smooth, and I suggest black-leading them to diminish friction.

10 *d* The upper end of the piston rod, with a parallel motion, with the levers, or handles, loaded with weights at the extremities to balance the piston.

10 *e* A wooden case on the working lever, or handle, to protect the hand from too great cold, or heat, from the metal of the lever.

10 *f* An inclosed channel, or shoot, for passing

the air pumped up, along under the deck, out through a port hole in the side of the vessel.

10*g* The port of the above port hole.

10*h* Cap scuttles and coamings to keep out wet.

10*i* A pump valve enlarged. The part within the rim supposed to be of parchment, like a drum head.

11 Narrow grooves open in front, with wire, in different lengths, looped together, to pass thermometers with down to different levels in the interior, with thermometers shown in the grooves.

11*a* Small metal plates crossing the groove in front, to keep the wire within it, on letting down thermometers.

11*b* The orifices at the top of the grooves, some closed with a plug.

11*c* Thermometers placed above deck, just over those below in the interior, with a pent board over them to shoot off rain.

11*d* Thermometers placed at the outside above water, with guards, to shelter them from the sun's rays, and allow the air freely to pass up and down within the guard.

11*e* Two thermometers shown in the lattice work nearest the head of the vessel.

11*f* A thermometer placed at the entrance of the hollow shaft.

11*g* A thermometer for the outside, a case with an open groove for containing it, and a sun-guard, on an enlarged scale.

12 Gougings in the upper sides of beams, &c. immediately underneath the planks of decks, for the passage of the air.

13 Perforated battens to preserve passages for the air among packages of goods.

THE SPECIFICATION OF THE AUTHOR'S INVENTION UNDER THE LETTERS PATENT.

Note.—The Patent is for the Patentee's "Invention for preserving decked "ships or vessels, so as to render them less liable to the dry rot; and for "preserving goods on board such ships and vessels from damage by heat."

WHEREAS, &c.

Now know ye, that, in compliance with the said proviso, I the said John George do hereby particularly describe and ascertain the nature of my said invention, and in what manner the same is to be performed, as follows. That is to say: With respect to the nature of my said invention, the same consists in the making of the hereinafter described combination of the hereinafter described alterations in decked ships and other decked vessels for the purposes of navigation, and of the hereinafter described apparatus and machinery to be placed and used on board of the same, for causing and keeping up, when and as often as is requisite and the safety of the vessel will permit, a regulated supply, circulation, and change of the common air of the atmosphere, in and through the interior, or any particular part of the interior, of such vessels, for thereby and therewith, as often as is practicable and occasion requires, causing heat to enter into or to pass off from the same in and along with such air, for bringing and preserving the temperatures at the opposite sides of the timber of such vessels near to an equilibrium or the same temperature, and thereby preventing, either wholly or as far as is practicable by the means used, any current or stream of heat, or any considerable current or stream of heat, from penetrating the timber of such vessels on one side of the timber, and passing through its substance and out of it at another side thereof, for the better preservation of such timber

General description of the invention.

from the said premature decay and decomposition of timber, commonly called the dry rot; and, also, by so causing heat to pass off out of such vessels, for the better preservation of goods on board thereof from damage by heat*.

Its general and leading principles.

Before proceeding particularly to describe the said alterations, apparatus, and machinery, I shall, for the readier understanding of my said invention, state some matters chiefly explanatory of its more general and leading principles. The reason for seeking to prevent any current or stream of heat from passing through the timber as before mentioned, for better preserving it from dry rot, is, that, when that kind of decay of timber takes place, it is commonly (if not always,) where the temperature of the air, or earth, or water, and other substances in contact with and near to the timber on one side of it is higher than the temperature at the opposite side, and where the timber is placed in such a situation and circumstances as that a current or stream of heat, more or less rapid or considerable, issuing from the substances of higher temperature on the warmer side, is commonly passing through the timber from the warmer to the colder side, and out of it into the colder substances at the latter; and that, in such case, it is the heat coming into immediate contact with every part of the interior of the timber in such its passage through it, and exerting an action of some sort on it, and on any wet (if any,) that happens to be contained within it, that, by degrees, when the action of the heat is sufficiently quick, and is continued in the whole sufficiently long, causes the decay.

For further conducing to the readier understanding of my said invention, I next state, that the reason why any such passage of heat through the timber is sought to be prevented by means of a regulated supply, circulation, and change of the air of the atmosphere, as before mentioned, is, that heat readily both enters and leaves atmospheric air, and that, where timber is situated as before described, while such a regulated supply,

* The reader is apprized, partly as an excuse for the complexity and length of what he has just read, that it describes all that the invention proposes to effect, with certain qualifications, for greater caution, to prevent it from being misconstrued to pretend to more than it can accomplish.

circulation, and change of colder air on the warmer side of the timber, or of warmer air on the colder side will bring the temperatures on the opposite sides towards an equilibrium, and will thereby prevent or lessen any passage of heat through the timber; an immoderate and unregulated supply of such air may be such as to convey such a quantity of heat to or from the timber as to produce the evil, by causing a current of heat to set through the timber from the opposite side to that which was at first of the highest temperature.

Further, as to so much of the said combination constituting my said invention as is for the passing off of heat from the interior of vessels, the same comprises the following principal parts.

First, A separate passage or hollow shaft is to be made of some solid material impervious to air, and placed upright within the vessel, so as to descend from the deck or upper deck sufficiently low down in the interior for introducing colder air, without allowing it to mix with the mass or body of air already in the vessel, directly down to near the lowest level from which the passing off of heat may be required: and hollow trunks or other enclosed passages, with sides impervious to air, are to be made and to be attached to such shaft so as to communicate internally therewith, for conveying the air to the several parts of the interior from which the passing off of heat is required; and where the depth of the vessel, and the quantity of heat which it may be required to pass off, are sufficiently great to render it necessary, the said trunks are to be joined to the shaft at different heights or levels, in order to convey the air to the parts where it is needed, at different heights or levels, as occasion requires; and on each occasion of introducing colder air, it is to be conveyed as near as conveniently can be to the lower level of the part from which the heat is to be passed off.

Secondly, The said trunks are to be furnished at different places at proper distances from each other as hereinafter mentioned, with sliding hatches or other suitable contrivances for regulating the size of the passages for the air through the trunks at such places, and, consequently, the quantity of air permitted to pass. And beyond these hatches (reckoning from the shaft,) are to be orifices for the issuing of the air from the

trunks, and these orifices are to be furnished with valves as hereinafter described, constructed so as to open by a slight pressure of the air, and permit it to pass out of the trunks, and to shut, of themselves, on the ceasing of the pressure, and prevent the air from returning.

Thirdly, Separate apertures, to be situated at proper distances from each other as hereinafter mentioned, are to be made in the highest parts, or decks, forming the roofs of the several holds, rooms, and other places into which the colder air is introduced, for the passing of it off, after circulating therein, together with the superfluous heat that has become mixed with it, out of the vessel, into the open air; and each of these apertures is to be furnished with a valve, such as before mentioned, for permitting the air to pass out and preventing its return.

The use or object of the hatches for regulating the quantity of air to be permitted to pass, is to prevent any such consequence as before mentioned, from an immoderate and unregulated introduction of colder air into the interior of a vessel. And the reasons for admitting colder air in the first instance by a distinct passage down to near the lowest parts of the vessel requiring the passing off of heat, and for conveying the same by hollow trunks or enclosed channels to the lower parts of the several places or levels where colder air is required, and for passing it off after it has circulated therein by separate apertures in the highest parts of such places, are, that colder atmospheric air is, ceteris paribus, specifically heavier than warmer air, and that when the outer air is colder, and is in fact specifically heavier than the air in the interior of a vessel, if it be introduced below the body of warmer air in the interior, it will, by its greater weight, and the weight of the column of outer air which continues to supply it, push the warmer air before it up through such apertures out of the vessel; and, as it becomes warmed, it will be itself pushed up and out in its turn; and that, thus, a more quick and regular circulation and change of such air, and passing off of heat, can be caused, than there could be if the colder air were only brought immediately over the body of warmer air contained in the interior of a vessel in contact therewith; or than if, although conveyed as low down as required, it were not conveyed along within the interior to the

parts where required; or than there could be if no other aperture than that by which it was introduced were provided for the passing of it off when heated.

Other parts of the said combination constituting my said invention consist of apparatus and machinery hereinafter described, as well for removing out of the vessel such heavy gases or air as would otherwise by their weight stop or prejudicially lessen the before mentioned introduction, circulation, and change of air for passing off heat, as for introducing the air of a higher temperature, which is to be introduced into any part of the interior; and which is to be introduced by removing the colder air already therein, and thereby causing the warmer outer air to descend into the vessel and take its place; and for which purposes such apparatus and machinery are to be constructed, (as hereinafter described,) in such a manner as to be capable of receiving the heavy gases, or heavy or colder air, at the lowest part of the hold, and at such different heights or levels above the lowest as any material differences of temperature are liable to be found at, or at any one only, or any more of such heights or levels, at pleasure.

For ascertaining when to introduce into any, and what, parts of the vessel either warmer or colder air than that already therein, thermometers are to be provided and used for taking observations of the temperatures, at the same time, of the air within the vessel and of the air and water at the outside, at places immediately, or as nearly as practicable, opposite each other at the opposite sides of the timber of the vessel, and at such depths or levels, and at such distances from each other, at the same depth or level, as any material differences of temperature are liable to be found at; and on such temperatures being ascertained, and any such differences of temperature found, the principal object will be, by means of introducing and passing off colder or warmer air, as the occasion requires and the circumstances of the case will admit of, to bring the temperatures on each side of the timber as near to one and the same as is necessary, or may be practicable by the means used, to prevent, as before mentioned, either wholly or as far as is practicable, the passage of heat through the timber.

Particular description of the invention.

Having made the foregoing statements for conducing to the readier understanding of the general nature and leading prin-

ciples of my said invention, I next proceed particularly to describe and ascertain the nature thereof, and in what manner the same is to be manufactured and performed.

Alterations and apparatus for admitting colder air and passing it off when heated. 1. For admitting it. A distinct passage down to the lower parts of the vessel, by a hollow shaft.

With respect to the alterations to be made in the vessels, instead of constructing them, or suffering vessels already built to continue with only common hatchways, or other entrances into the interior thereof, in the manner and for the purposes now used, make, in addition thereto, at or as near to the middle of the vessel as conveniently can be, an opening through every deck, directly down to the bottom of the hold. In this opening (the most convenient form for which will be square,) construct and fit a hollow shaft, or passage for the air, reaching from the deck or upper deck down to the level of the top of the kelson. This shaft should be of timber or some other substance impervious to air, and the less pervious it be to heat the better, and its sides and bottom are to be air tight in every part, except where there are to be apertures therein as hereinafter described. By placing the shaft at or about the middle of the vessel, its lower end will continue of a more equable depth in the water in the different changes in position of the vessel, and the trunks hereinafter mentioned, communicating therewith, will be of more equal lengths.

Provide, for the opening in the deck for the shaft, a coaming with a common hatch for closing the same when necessary.

A part of the shaft to be moveable, to be raised above deck when in use.

Construct and place within this shaft another hollow shaft made to fit and slide up and down in the former, and so as when drawn up to constitute with it one hollow shaft consisting of two parts, one part fixed below deck, and the other moveable up and down within the first. Make the moveable part open at the bottom, and make it of such a length as, when fully raised up, to reach above deck to a height of from three or four of its diameters in the largest sized apparatus, to five or six diameters in the smallest, and make it to let down in the other part so far as for its top when down to be just below the level of the lower side of the deck. Any adequate tackle may be used for raising and lowering the moveable part of the shaft, and sustaining it at any required height. The opening in the deck being square, the shaft will be rectangular with equal sides. Make the moveable part of it at the four corners and at the top and bottom of a suf-

ficiently strong frame-work of carpentry. Make a cover for the top projecting sufficiently on every side to shoot off rain.

Immediately below the frame-work of the top of the moveable part of the shaft, make in each side of it an oblong aperture equal to the area of the hollow within. Provide each aperture with a shutter or sash fitted into suitable grooves, so as to slide up and down after the manner of the window-glasses of a coach, or the sash of a sash-window, and so as, when drawn quite up, to close such aperture. And provide and attach to each shutter a web perforated with holes at small distances from each other, for hitching the same on a projecting metal button at the bottom of the aperture, for pulling the shutter up and down with, and sustaining it at different heights according as may be desired, or provide any other convenient means of effecting the same purposes.

Apertures for the air.

Sizes of, to be regulated.

For using the shaft, raise the moveable part above deck, and lower one or two of the shutters, and lower the most leeward or the most windward shutters, according to the quantity of wind and the quantity of heat which it may be required to pass off from the interior.

The principal objects of providing a moveable part of the shaft to stand up a certain height above deck, when in use, are, first, to catch the wind; secondly, to regulate with more facility and exactness the size of the apertures for the entrance of the air; and thirdly, to provide the higher or taller a column of descending air within it for more quickly overcoming occasional checks to its entrance into and circulation through the interior.

Attach to each side of the shaft fore and aft, in apertures to be made therein, just above the level of the kelson, a hollow trunk or other such enclosed channel for the passage of the air from the shaft, extending in as straight a line and as nearly along the middle of the vessel as practicable, through every bulkhead or partition, and round or (if necessary) through the step of the foremast, sufficiently near to each end of the vessel to convey the air thereto, and continue the trunk for its whole length at nearly the same height above or distance from the kelson. And in case there be any separate enclosed places at either side into which the trunk does not enter, attach lateral trunks to it to reach into such places at their lowest parts. Insert in the bottom of

Hollow trunks for distributing the colder air where required.

the shaft an air-trap to permit water to drain into the well, and to intercept the further downward passage of the air.

Trunks at different levels over each other, in certain cases.

In cases of holds or other places of such a considerable depth as that it may sometimes be required to pass off heat from the upper parts thereof, while the temperature of the lower parts thereof ought not to be lowered, attach to each side of the shaft fore and aft, as before mentioned, in the same hold, over each lower trunk another trunk, with any necessary lateral trunks thereto, to extend near to each end of the vessel, and into any separate enclosed places situated at either side of the leading trunk as before mentioned, and join the same to the shaft at such a height above the lower trunks as any material difference of temperature is liable to be found at; and place the additional trunks so as that they may have a sufficient rise from the shaft to their farther ends for any water that may possibly, in some circumstances, collect therein, to readily drain into the shaft when the vessel is upright. And fix and suspend the additional trunks from the roof of the hold, or from any beams crossing the same, situated below those of the deck forming such roof, at the required height. And, in general, an advantageous situation for such additional trunks will be at about half the height between the lower ones and the roof of the hold, unless the level of the water line is somewhat higher than this, and is at the same time some feet below the roof; in which case the additional trunks may advantageously be placed somewhat higher than the mid-height, in order to be nearer the level of the water line. And to specify a particular depth of hold as sufficient to render such additional trunks desirable, I recommend the same for any hold more than ten feet deep above the lower trunks; and I recommend further additional trunks for each further depth of hold of from eight to ten feet, according to the greater or smaller quantity of heat likely to require to be passed off therefrom. Where, however, the depth of the hold is such that, according to the directions above given, it will not require more than one level or main of trunks, instead of placing them as directed just above the level of the kelson, place them at about one fourth of the height of the hold above such level.

Trunks, where more than one deck.

Where the vessel contains more than one deck, provide an additional set of trunks for supplying colder air to each space

between the decks. And for this purpose the trunks may, as may be deemed most convenient, either be placed upon and along the deck forming the floor of the space between decks to which they are to convey the air, or be placed at the underside of such deck; in which latter case, attach other trunks to them, to pass vertically up through apertures to be made in such deck into the several places immediately over it; and there make and construct such last mentioned trunks so as to turn and be bent at right angles to the vertical rise thereof, a sufficient length for inserting therein the sliding hatch and valve hereinafter mentioned and described. And where the vessel contains a quarterdeck, poop, or forecastle, in order to convey colder air to the cabins and other places situate immediately underneath the same, attach one or more upright trunks, as may be most convenient, to the trunk for supplying the air to the places next below the deck forming the floor of such last mentioned cabins and other places, and pass such upright trunk or trunks directly up through such deck, and there construct the same so as to be capable of receiving the like hatch and valve as last mentioned.

Make the trunks rectangular, and of timber or other materials little pervious to heat.

Orifices in the trunks for the issuing of the air.

Make one or more orifices for the issuing of the air from the trunks in each separate enclosed place throughout the interior. And the distances of such orifices from each other in the same hold or place should be greater or less according to the greater or smaller quantity of heat liable to require to be passed off from the particular place; and I recommend that such distances be from about twenty to thirty five feet. And wherever an orifice is required in any trunk (except at its farther end from the shaft,) attach a square hollow projection or box to one of the sides of the trunk, to communicate by an aperture in such side internally therewith; and make in the top of the projecting part a circular orifice for the issuing of the air; and make a like orifice in the top of each trunk itself near its farther end.

Sliding hatches in the trunks to regulate the quantity of air permitted to pass.

Place so as to cover and slide up and down against each such aperture in the side of each trunk, and also in and across the trunk itself, near the orifice at its farther end, but between the orifice and the shaft, a sliding hatch, or other such contrivance, made to draw in and out, and constructed so as to admit of being

kept drawn in or out to any greater or lesser extent, at pleasure, for regulating the size of the aperture for the passage of the air through the same.

Valves to permit it to pass into the different holds, &c. and prevent it from returning.

In each orifice place a valve that will permit the air on a slight pressure to pass out of the trunk, but prevent it from returning. How to make such a valve is hereinafter pointed out. Make the orifice for the lower half of the thickness of the board or other material of the trunk, or its projecting part, of an inch smaller diameter than for the upper half, so as that there may be a ledge half an inch broad all round for the valve to rest on within such orifice. For protecting from accidents each valve not otherwise protected, place a coarse wire grating over and round it at a few inches from it.

Means of getting at the valves when situated below goods.

Whenever any of such hatches, valves, and orifices are situated in a part of the vessel where they will be at a depth below goods, make and fix a lattice-work of carpentry round the hatch and orifice to reach above the goods, and make it sufficiently wide or large for passing the valve up and down within it, and for it also to contain a rod of wood or metal to be attached to the hatch for drawing it in and out. And in case the goods are to be stowed so high as to leave no sufficient room in the same hold or place for passing to the rod, continue the lattice-work up to the deck above, and make an aperture through the deck for passing the valve, when necessary, up and down through it, and for there raising and lowering the rod, and sustaining it at different heights as may be required, and also for letting down thermometers within the lattice-work to different depths in the interior. Provide for each aperture a plug or cap-scuttle, with a notch in it for the rod to pass through, and make it to fit both the aperture and the rod, for securing the former, when necessary; and provide also a jointed rod with a hook at one end, such as hereinafter respectively described, for taking up and letting the valve down with.

Battens perforated with holes for the circulation of the air, to be placed under and between goods.

For the quicker circulation and change of the air in and through the interior, and the consequent quicker introduction or passing off of heat into or from the same, and more especially for the quicker passing off of heat from goods liable to damage by heat, provide a sufficient number of loose rectangular battens of wood, at least twice as wide as thick, perforated through the

two narrower sides with holes as large and numerous as the requisite strength of the battens, for the purpose for which they are intended, will permit; and, in stowing the goods, place the battens at convenient distances from each other, both under and between the several tiers and rows of bales, casks, or other packages, so as to preserve passages for the air between each tier and row, and so as that the perforations in the battens will admit the air entering from the valves of the trunks freely to circulate amongst the goods, and readily pass off after circulating between the same.

Alterations for facilitating the passing off of the heated, or the introduction of warmer air; viz. making narrow apertures between the top parts of all beams and bulkheads and the planks of the deck above, for the air to circulate through them in every direction immediately under the different decks.

As well to prevent heated air from remaining lodged against particular parts of the underside of any deck, as for the quicker introduction of warmer air, when necessary, make and leave immediately beneath the planks of the decks open spaces of about one third the width of each plank, and of the depth of from three quarters of an inch to an inch and a half, for the passage of the air between such planks and the beams, ledges, and carlings, or other supports thereof. And in making this alteration in vessels, pay due regard to preserving them of proper strength. And, for this purpose, I recommend giving to the beams and the other supports of the planks of the decks an increased depth, equal to two thirds of the depth of the open spaces intended to be left, and to make curved gougings of the length and depth above designated in and across the upper sides of such beams and other supports. Also leave the like open spaces at the tops and bottoms of all bulkheads, or other partitions, in the interior, save that the open spaces at the bottoms of bulkheads and other partitions may properly be of little more than half the dimensions of those at their tops.

Apertures for the passing off of heated air, or introduction of warmer air, as occasion requires.

If the open spaces just described are left under the planks of decks, and at the tops and bottoms of bulkheads, openings for the passing off of the heated air will not be necessary in the upper part of every small separate enclosed place, but otherwise, such an opening should be made in the centre of the highest part or roof of every such place. With respect to holds and any rooms, cabins, or other enclosed places of considerable dimensions, situated underneath any deck, separate apertures for the passing off of the heated air, or the introduction of warmer outer air, as the occasion requires, are to be made at proper

distances from each other, in different parts of the deck; and they should be so arranged therein as to best facilitate the passing off, or the introduction, of the air, in every position in which the vessel may be. And for this purpose the same should be situated near the sides and ends of the vessel; and I recommend that the same be placed at least twice as near the sides as the middle; and that their distance from each other be from twenty to forty feet lengthwise, and from fifteen to thirty feet crosswise the vessel, according to the larger or smaller quantity of heat likely to require to be passed off from, or introduced into, the whole interior, and into the particular parts with which the particular apertures communicate. If the open spaces above described are not left under the planks of the decks, the apertures should be the closer to each other. These apertures are to be circular for receiving the valves next hereinafter described.

Valves for permitting the heated air to pass out and preventing its return.

For regulating the passing off of heated air and preventing its return, place in each of such apertures a valve, with the working part of it composed of some light elastic substance that will readily yield to a slight pressure of air, and will, from its elasticity, have a tendency to resume its first shape and position on the ceasing of the pressure; and construct and place the same so as to open outwards and permit the air to pass out of the vessel, and to shut on any opposite pressure, and prevent any air from passing inwards. And the lighter, the more flexible, elastic and strong, and the less liable to absorb much moisture from the air such substance may be, it will be the better adapted for the intended purpose. And, at present, I know of no material in which these properties are so well combined, or that will answer the required purpose so well, as thin superfine writing paper; which material will answer the required purpose.

Any mode of making a valve that will readily act in the way mentioned, will be sufficient as well for the admitting trunks for colder air as for the discharging apertures for heated air. But lest any person should not know how to construct such a valve, I describe and recommend the following as one that will answer the required purpose.

How to construct a valve

Cut a thin board into a circle twelve inches in diameter. Describe on it two concentric circles, one ten inches, and the

other two inches in diameter. From the centre of the board to the ten inch circle draw eight equidistant radii. From the inner circle to the ten inch circle draw a straight line on each side of each radius, three sixteenths of an inch therefrom, and parallel thereto. Cut out all the parts of the board situate between the inner and the ten inch circles, and not enclosed between the parallel lines. There will thus be eight arms extending from the inner circle to the ten inch circle, with an outer circular rim one inch broad. that will answer the purpose.

Cut three pieces of writing paper into circular figures, one eleven inches, another seven inches, and the other three inches in diameter. Perforate each piece in the centre, and bore a small gimlet hole through the centre of the board. Procure a round metal pin of a size to fit, but readily pass through, the gimlet hole, with a circular head an inch in diameter, flat on the side next to the shank, and with a screw round the shank, commencing at a distance from the head somewhat less than the thickness of the pieces of paper and the board. Provide a nut with a screw, to screw on the shank of the pin; and for greater quickness in screwing it on and off, make it a horned or forked nut. Pass the pin through the holes in each piece of paper, beginning with the smallest, proceeding to the next in size, and ending with the largest piece; and then pass it through the hole in the board, and fasten it on the opposite side, by screwing on the nut sufficiently firm to prevent so much of the paper as is under the head of the pin from having any play. The pieces of paper will thus rest on and cover the centre and arms of the board, and the largest piece will lap half an inch over the ten inch circle, and together with the other pieces it will yield to a slight pressure of air acting from the opposite side of the board, and permit such air to pass through; but the same, on the ceasing of such pressure, will immediately shut, and will prevent any air from passing in the contrary direction. The use of the smaller pieces of paper is, by their elasticity, to protect the largest piece, and each other, from being crumpled up and doubled by any sudden gust of wind, so as to fail of resuming their first shape and position on the ceasing of the wind. And according to the force of air to which the same will be exposed, and the size of the valve, no such smaller piece of paper may

be required, or one such may be sufficient, or more than two such may be found necessary. Instead of using a board, as above supposed, for the seat or parts of the valve for which a board is above supposed to be used, it will probably be cheaper to make use of cast iron painted, or other metal.

The apertures in which to put the valves for permitting the passing out of heated air.

For the valves for permitting the passing off of heated air the apertures through the deck should, as above stated, be circular. The valve must either be put down into the aperture from above, or be put up into it from the underside. If the valve is to be put down from above, make the upper part of the aperture, for a depth equal to the thickness of the valve, a little more than twelve inches in diameter, and make the rest of it a little more than ten inches in diameter. If the valve is to be put up from the underside, make the rim of the valve itself half an inch broader than it will be according to the directions before given, and so as to make the diameter of the whole valve thirteen inches; and make the bottom part of the aperture, for a height equal to the thickness of the valve, a little more than thirteen inches in diameter, and make the rest of it twelve inches in diameter. Put the valve up into the aperture from the underside, and support it with three or four hasps or spring bolts, to be fixed to the underside of the deck close to the aperture, and to be placed so as to hasp or bolt under the rim of the valve. Where goods are to be stowed close up or near to the underside of any deck, the valve must be let into the aperture on the upper side. And supposing the aperture to be situated in an orlop or other inner deck on which goods are also to be stowed, the chimney to be provided for the valve, as hereinafter mentioned, must (in like manner as the lattice works before described for the admitting valves) be of a sufficient diameter for letting down and drawing up the valve through it from above. That side of the valve, to the centre of which the paper or other light elastic substance is fixed, is always to be kept uppermost; and, for greater facility in changing the paper, when necessary, provide the head of the centre pin with a thumb-piece; and, when the valve is to be situated at a depth below goods, instead of a mere thumb-piece, provide the head of the pin with a fixed ring handle, or eye, for letting the valve down and taking it up with, by means of a hook to be attached to the end of a rod of wood,

composed of several pieces with joints, with metal hinges, at lengths of three or four feet from each other, constructed so as for the rod to fold together, in order to admit of being used, when necessary, in low places between decks, for letting the valve low down into or taking it up from a deep hold. The pieces of wood for the rod should be flat-sided, and be as thin as is consistent with their having the requisite strength; and the bottom of the hook, instead of being curved, should be made straight, with a notch across it at the underside, for pressing the valve down home into its proper seat or rebate, without endangering tearing the paper with it by its slipping; and the direction of the hook should be in the same plane with the wider sides of the rod; and the most convenient shape for it will be with the shank somewhat bent out of a straight line, so as to form a heel at the back of the hook, as in the common shape of irons for drawing on boots.

Chimnies for discharging the heated air to be placed over the discharging valves above deck.

Round the upper orifice of the aperture for the discharging valves, place a tube of timber, or other materials little pervious to heat. This tube is to perform the office of a chimney for the heated air after passing through the valve; and it is to be made sufficiently large for that purpose, and is to admit of being removed, or raised, and lowered, for putting in or taking out the valve from within it, if necessary, as occasion requires. If the chimney be of timber, it will be best to make it of separate staves, to be kept together by metal hoops, with screws constructed so as to screw into a smaller compass, in proportion as the timber shrinks by dryness and the metal of the hoops lengthens by heat. Where the aperture is in an inner deck or platform, continue the chimney up through the outer deck. At a convenient height above this deck, as, for instance, two feet above it, attach to the chimney a top of metal for the passing off of the heated air, without permitting rain to fall into it. Make the top of so much larger a diameter than the lower part of the chimney, and of such a length, as to descend a few inches below the top of the latter, on the outside, at a sufficient distance from it, to leave room for any water deposited against the inner side of the top to trickle down it, and drop into any receptacle to be placed for the same on the deck, instead of running down into the lower part. And with the same

view, and to prevent, as far as practicable, water from dropping on the valve, make the upper part of the top on the inside convexed, so as to make the hollow within it shaped like a sugar-loaf. This top may be made either so as to remain fixed, or to revolve with the wind. If it be made so as to remain fixed, make it of a sufficient diameter for the passing off of the heated air between it and the lower part of the chimney, as well as for the trickling of any water down it as before mentioned. If the top be made so as to revolve with the wind, make it curved at its upper part, so as to pass the air off horizontally when the vessel is upright; and in order that it may the more evenly balance, and act properly in the changing positions of the vessel, construct it with as much accuracy as it conveniently can be for causing its centre of gravity to be in the centre, and equidistant from the ends of the axis round which it revolves.

Wherever an aperture is directed in a deck, provide a coaming, with a cap-scuttle, or other proper means of securing the same, when necessary.

As to assigning specific dimensions for the different parts of the apparatus that have been described. General rules for judging of the most proper and advantageous sizes.

With respect to specifying the most proper and advantageous dimensions for the hollow of the shaft, the trunks with their orifices, and the apertures for the discharging valves, the size of the shaft and the sums of the sizes of the trunks and discharging apertures should be proportioned to the quantity of heat likely to require to be passed off from the interior; and this will depend principally on the size of the vessel, the heat of the climate, the liability of the cargo or other goods to generate and give out heat, and the number of persons or living creatures on board. The more the heat which the goods on board are liable to give out, and the greater the number of persons or living creatures within the vessel, it is obvious that the larger will be the quantity of heat to be passed off. And with respect to the size of the vessel and the heat of the climate, the larger the vessel the greater in proportion to the area of its outer surface will commonly be the quantity of solid contents contained within it, which will be alternately penetrated and left by heat, with changes of the temperature of the interior and of the outer air and water; and consequently the quantity of heat to be passed off will be greater in proportion to the solid contents, and not merely in proportion to the outer surface of

the vessel. And, as respects the climate, the hotter the climate the greater and quicker (as a general rule,) will be the changes of temperature; and, at the same time, in consequence of the more expanded state of the air by the heat in hot climates, there will be less air for the heat to mix and pass off in and along with, through any aperture of a given size; and consequently on both these accounts the passages ought to be the larger in proportion to the greater heat of the climate. Again, the more pervious the timber may be to heat, and the worse its quality for resisting its decomposing action, it will require the temperatures on its opposite sides to be brought more nearly to one and the same, than timber of superior quality. These considerations, while they show the general grounds on which to judge of the most proper and advantageous sizes for the several passages aforesaid, show that the nature of the subject will not admit of any precise directions, as to any specific dimensions, as being the most proper and advantageous, either in all cases or in any particular case. But, with this understanding, the following general rules may be advanced. First, make the several passages somewhat larger than may be thought strictly necessary, rather than endanger their being smaller; because increasing the dimensions of any passage for air will serve to the passage of a greater quantity than in an arithmetical proportion to the increase of dimensions. In the next place, make the sum of the sizes of the channels of the trunks, immediately attached to the shaft, somewhat larger than the hollow of the shaft itself, to compensate for the greater hindrance air meets with in its passage through smaller channels than through larger ones; and do the like with any trunks that are branched into two or more; and diminish the size of the shaft below any levels at which trunks are attached to it, in proportion to the smaller quantity of heat likely to require to be passed off from below such levels; and reduce the dimensions of the trunks in like manner, where they are continued beyond any orifices in them for the admission of colder air into the interior.

Inferior timber.

The subject does not admit of any positive prescribing of any precise size as the best.

With respect to the sizes of the orifices in which to place the admitting valves, and of the apertures for the discharging valves, study to apportion their dimensions to the quantity of

Sizes of the orifices for the admitting and discharging valves.

heat likely to require to be passed off from those parts of the vessel with which they respectively communicate, and study to make the sum of the sizes of the latter larger than of the former, in proportion to the degree of expansion the air will be liable to undergo by the heat, while in the interior. And the object ought to be to so apportion the size of each aperture to the quantity of air which it may be required to cause to pass through it, as that, on the one hand, it may not be too small for the reasonably quick passage of the air through its valve in sufficient quantity, when the greatest quantity is required to pass, or, on the other hand, too large for the force of the air to work the valve when the passage of but little air through it is required.

Subject to the above declaration, a particular case supposed, and particular sizes for the shaft and other passages mentioned and recommended.

Subject to what has been stated, I now proceed to suppose, and put by way of example, a particular case, and to point out the sizes which I recommend for it, as being, in my judgment, the most advantageous for the hollow of the shaft, and the other passages aforesaid. Supposing then a merchant vessel to be of ordinarily sound and well seasoned oak, and to be of 400 tons burthen, register measurement, and to be intended to trade to places not situated within or very near the tropics, and to carry cargoes not subject to generate and give out heat in any considerable quantities, and to have no greater number of persons on board than the common and usual crew of a merchant ship of the same burthen; I recommend constructing and making the shaft with the area of its hollow or passage down to the uppermost trunks, from two feet to two feet three inches square. To compensate for the increased hindrance to the passage of air through smaller channels than through larger ones, I recommend that the sum of the sizes of smaller channels immediately communicating with a larger one, supposing the number thereof to range from two to six, be made from about one fifth to about one third part greater than the larger channel.

The like for the discharging apertures.

And with respect to the sum of the areas or sizes of the apertures for the discharging valves, I recommend making the same about one-fourth part larger than the sum of those of the admitting valves.

General rules for other cases.

From what has been already stated, it follows, that, for other cases, the dimensions of the several passages for the air ought to be larger or smaller than in the

case put, according as a greater or smaller quantity of heat, under the same circumstances as to climate, is likely to require to be passed off. Supposing the timber of a vessel to be of inferior quality, the nearer ought the temperatures on its opposite sides to be brought to an equilibrium, and the more extensive and nicely adjusted ought to be the means of so doing. But it is impossible to form a judgment, as to what, if any, practicable approximation of temperatures to one and the same on the opposite sides of timber of very inferior quality would be sufficient to preserve it for any considerable length of time from dry rot; and it will be better to avoid using any such timber in any vessel, where good timber can be procured, than, by using such, to be obliged to endeavour to preserve it from dry rot, by bestowing for that purpose extraordinary care, pains, and attention, which may, nevertheless, fail through the worthlessness of the timber.

Preservation of goods.

With respect to the preservation of goods on board ship from damage by heat, every passing off of heat from the interior of a vessel will tend to preserve goods on board, liable to damage by heat, from sustaining such damage. And the combination of means, which I have invented, and been describing, of passing off heat from the interior, by the circulation and change of air in and through the same, and between the several tiers and rows of goods on board, as above described, will pass off such heat from the goods, for the better preservation thereof from damage by heat, in like manner as, and at the same time that they pass it off from the timber of the vessel.

Apparatus for introducing warmer air, by removing the colder from different depths or levels, &c. at pleasure.

I now proceed to particularly describe and ascertain so much of the said combination composing my said invention, as consists of the apparatus and machinery to be made and provided, as well for removing out of the vessel such heavy gases or air as would otherwise, by their weight, stop or prejudicially lessen the before mentioned introduction, circulation, and change of air for passing off heat, and (in so removing such gases or air,) being subsidiary to the shaft and admitting trunks for introducing colder air, as for introducing the warmer outer air which is to be introduced into any part of the interior, the temperature whereof requires to be raised; and which warmer air is to be introduced by removing the colder air already in the

interior, and thereby making room for, and, by providing in proper situations openings for the entrance of such warmer air, causing it to enter the vessel, and take the place of the former. For effecting these objects, the apparatus or machinery is to be made and constructed, so as to be capable of receiving the gases or air, which are to be removed, at different depths or levels in the interior, and also at different points, lengthwise of the vessel, at or near the centre and each end, as occasion may require. For this purpose make and fix in the vessel, at or as near the middle of it as conveniently may be, a square hollow trunk, made of timber, or other materials, of sufficient strength, and little pervious to heat, and place the same so as to descend straight down from the lower side of the deck or upper deck, to within about a foot of the bottom of the hold. This trunk is to be closed at its lower end with an air-tight bottom. In that one of its sides facing the sides of the vessel, which is nearest the middle, make, at different heights, oblong apertures, of sizes a little larger than the area of the hollow of the trunk. Make the lowest aperture close to the bottom; and make each succeeding aperture, situated in the same hold or place, at a height, according to the greater or smaller quantity of warmer air it may be required to introduce, of from six to eight or nine feet above the one immediately under it; and place them at equal distances from one another, and from the deck immediately over them. Where a vessel contains more than one deck, make also such an aperture in the trunk, just above the level of each deck, below the upper one. Provide these apertures with wooden doors or hatches, or other fastenings, for closing the same from the outside of the aperture; and provide rods of metal, or other means of raising and lowering such doors or other fastenings, to be attached thereto, and to reach to near the underside of, or up through, the deck, or upper deck, as may be judged most convenient, for therewith there opening and closing such apertures: and make such doors, or other fastenings, so as to shut as air tight as they conveniently can be made.

A square trunk descending to near the bottom, provided with apertures and doors at different heights, so as to receive the air from different levels.

For removing colder air from any cabins, or other places situated immediately underneath any quarterdeck, poop, or forecastle, or removing it more quickly from any part situated

at or near either of the ends of the vessel, below any deck extending from end to end, while any intervening part situate nearer the descending trunk is already of a temperature sufficiently high, make other apertures of a little more than half the dimensions of the former, in each side of the trunk, fore and aft, at about the level of the middle height of the hold, and also just above the level of any inner deck; and make these apertures circular, and provide them with sliding hatches and rods, or other means of opening and shutting, and keeping them air tight, in like manner as the other apertures. And for removing the air from any such last described parts of the vessel through these apertures, provide for each a hose of stout leather, or other strong and lasting air tight material, of a diameter equal to that of the aperture, and attach one end thereof to each aperture, and continue the hose into the parts from which the air is to be removed; and, where necessary, pass it up through apertures to be made in the deck, forming the floor of any cabins or other places, situated as above described, immediately underneath any quarterdeck, poop, or forecastle. And also, where necessary, protect such hose from pressure by goods, by passing the same through a loose hollow trunk, open at both ends. And such hose, as it approaches any separate rooms situated side by side, or one over another, at or near either end of the vessel, should be branched into two or more, and be continued into each of such rooms; and in such case provide a plug or other means of closing the orifice of each branch, in order that the colder air may at pleasure be received at the same time at one only or more of such orifices from one only or more of such rooms, as occasion requires. And if in any case it has been neglected or omitted to provide the perforated battens before mentioned, use other means of leaving passages for the air to flow through from each side and end of the vessel, to the descending trunk at the different levels of the apertures therein, as, for instance, by placing in proper situations for the purpose, between the goods or other things on board, an adequate number of other loose hollow trunks, open at both ends. The descending trunk being constructed as directed, it may, by opening any one or more of the doors or other fastenings to the apertures therein, and

Hoses for certain cases.

shutting the rest, be, at pleasure, made to receive the air which is to be removed at any one or more of the levels whereat the apertures are placed, and so as not to disturb the air situate lower down than the lower level at which the introduction of warmer air is required.

Means of passing off colder air through the descending trunk.

The descending trunk with the hoses being provided, any means adequate to the purpose may be resorted to for causing the gases or air which are to be removed to pass through the same up and out of the vessel. Such gases or air may always be caused to pass out by pumping up or removing the same by a pump or by a machine partaking of the nature of bellows, (respectively hereinafter next described), or, commonly, by means of a fire in a stove (also hereinafter described), to be respectively made to communicate with the descending trunk, at a part thereof situated above the uppermost of the before described apertures in its sides. Supposing it to be a pump that is to be made use of, the most convenient situation for it will be to place that part of it in which the piston is to work, and which may be called the piston box, close to that side of the descending trunk which is nearest to one of the sides of the vessel, and close under the deck, or upper deck, so as for the piston rod to be passed up through a hole in the deck for the purpose of being worked above deck. For causing the pump to communicate internally with the descending trunk, attach to the latter, a little below the level of the bottom of the piston box, a lateral trunk of the same diameter, and hollow within, as the descending trunk, and projecting from it a sufficient length for conveying the air to the central parts of the bottom of the piston box; and make in the side of the descending trunk and the top of the lateral trunk the proper apertures for that purpose. Make the piston box of large dimensions, in order to pump up a large quantity of air at each stroke. The most convenient form for it will be square; and make its sides within as smooth and even, and to fit the piston as exactly as they conveniently can be made, both for the more easy and the more effectual working of the pump. Provide the box with a cover, with a moderately air tight collar, for the rod to work in, and provide it also, just below the top, at the side next to the nearest side of the vessel, with a covered channel, or shoot, reaching along immediately under the deck to

Construction, &c. of a pump.

a port-hole, to be made in such side of the vessel, for discharging the air beyond the same. Construct the pump so as for the upper edge of the bottom of the piston to rise, in working, only to a level with the bottom of the covered channel or shoot. For the quicker and more easy passage of the air through the bottoms of both the piston box and the piston, furnish the central parts of the bottom of each with three common pump valves, to be placed pretty close to each other, and to be made of light, but sufficiently strong, materials, as, for instance, of leather, or of circular rims of wood covered with parchment, and to be respectively attached by hinges to the bottoms of the piston and the box. Make the sum of the areas of the apertures for these valves nearly twice as large as the area of the hollow of the descending trunk, and make the apertures in the piston box within a square space equal to about one third of the area of the box; and make this part of the bottom so much lower than the remaining part as will be sufficient to allow of the valves rising in working the pump, without being forced against the bottom of the piston. Continue the lower part of the box of the same dimensions for the depth of two or three inches below the valves. At this part complete the bottom, leaving an aperture in the centre to fit the aperture in the upper side of the lateral trunk communicating with the descending trunk; to the upper side of which lateral trunk it is to be attached. Make the area of the hollow of the above mentioned covered channel or shoot about twice as large as that of the descending trunk, and make the latter about one sixteenth part as large as that of the piston box where the piston works.

Particular dimensions for the pump in the case before supposed.

The piston box should be sufficiently large for pumping out all the air in the interior, above the level of the water line, sufficiently fast for the increase of temperature occasioned by the entrance of the warmer air, after allowing of the difference of temperatures which is still to remain between the interior and the exterior, to keep pace with any ordinary increase of temperature in the outer air. And, to suppose a particular case, by way of illustration and example, and specify for it particular dimensions for the piston box and descending trunk, I recommend, that, for such a case as that before supposed of the vessel of four hundred tons burthen, the dimensions of the interior of

the piston box, for the range of the piston, be about equal to a cube of four feet, so as to pump up at each stroke about sixty four cubic feet of air, and that the area of the hollow of the descending trunk be about one foot square.

Or, instead of a pump, a machine of the nature of bellows, except in being furnished with a larger passage for discharging than for receiving the air.

Instead of providing a pump to be worked with a piston, as above described, a machine may be made, and attached to the upper side of the lateral trunk which communicates with the descending trunk; differing in principle from common bellows only in having, instead of a common nozzle of smaller dimensions than the orifice for receiving the air for creating a strong blast, a passage, for the easy discharge of the air, of considerably larger dimensions than the area of the hollow of the trunk for supplying the air; for instance, of about double its size, and furnished with valves of corresponding dimensions, for permitting the air easily to pass out into such a covered channel or shoot as above described, for the pump, and for preventing it from returning. And in case of making and using such a machine instead of a pump, make it of a sufficient size for receiving and discharging in the same time an equal quantity of air with what is to be received and discharged by the pump, when a pump is used.

3d. By a stove constructed so as to be capable of drawing all its air for the supply of the fire from the descending trunk.

The removal of gases, or air, through the descending trunk may also, except in the possible case of the same being such as will not support combustion, be effected by means of a fire in a stove furnished with a tube or pipe, to be attached to the descending trunk at a part thereof above the uppermost of the before described apertures in its sides, and the stove to be constructed so as to be capable of receiving all its air for the supply of the fire through such tube and the descending trunk. And, in case such a stove be provided, make the area of the hollow of the tube somewhat more than half as large as that of the descending trunk, and place in the tube, near that end of it which is attached to the trunk, a sliding hatch, made to draw in and out across the tube; and this hatch must always be let in home whenever the pump or other machine last before described is worked. But in vessels of the largest sizes, and the higher rates of vessels of war, instead of attaching the tube from the stove to the before described descending trunk, it may be worth the expense, in order to have the power of using both the pump or other machine last before described, and a stove, at

Or, in some cases, from an optional additional descending trunk.

the same time, for removing the gases or air, to make another and additional descending trunk for the tube from the stove to be attached to.

In all cases of removing colder for causing the entrance of warmer air into the interior, open the door or other fastening of one or more of the apertures in the descending trunk situated the nearest to the lower level at which the warmer air is required. And where the colder air is to be removed from any part at or near either of the ends of the vessel, and for which the hoses are provided, open the door, or other fastening of the aperture to which the hose for such part is attached, and let one or more of the orifices at its farther end in the part or parts from which the colder air is to be removed also be open, as the occasion requires. On introducing warmer air into any of the upper parts of the interior, take out, and lay aside, the before described discharging valves for heated air, communicating more immediately with the parts in which the warmer air is required. And for the more regular introduction and diffusion or spreading of such warmer air immediately at the under side of the deck or roof of such parts, the other openings or entrances to the same should, in general, during the time of introducing such warmer air, be kept shut. In the possible case of its being required to introduce warmer air to the lower parts of the hold, the hatches in the admitting trunk in such part should be kept open, and the air should be introduced through the shaft and such trunk, although the same are intended, in general, only for the introduction of colder air.

Heavy gases, &c. to be removed.

Remove, as often as is necessary, any heavy gases or air, which, if suffered to remain in the interior, would, by their weight, stop or prejudicially lessen the circulation and change of the air admitted by the shaft. And the presence of a prejudicial quantity of such gases or air will be indicated, when there is such a difference of temperatures of the outer air at the shaft, and some part or parts of the interior, as that the hatches in the admitting trunks being drawn out, and the admitting and discharging valves being in proper order for working, there ought, supposing the air already within such parts of the vessel to be moderately dry, to be a circulation of air through such parts of a known ordinary degree of strength or quickness; but

it is found that either no circulation is taking place, or only a circulation materially less than there should be. And the absence or the degree of any such circulation may be sufficiently ascertained by placing any light substance in the upper part of the hollow of the shaft, and observing to what (if any) extent it is acted on by the air passing down the hollow. The pump or other machine before described will be sure means of removing the heavy gases or air in all cases, and the stove in all, except where the gases are such as will not support combustion.

Thermometers to be placed in situations particularly described.

For completing the said combination composing my said invention, it remains to make and provide a sufficient number of thermometers, with the means hereinafter mentioned of placing and arranging them in the different parts of the vessel hereinafter pointed out, for ascertaining, by means of such thermometers, when it is expedient to introduce into any and what part or parts of the interior air either colder or warmer than that already therein. In order to this, the temperatures immediately at the opposite sides of the timber of the vessel, both in the interior and at the outside, and as well below as above water, must be ascertained, as completely as practicable, at as many situations or places as any material differences of temperature are liable to be found at. For this purpose, with respect to the interior, I recommend placing thermometers against the ends and sides of the vessel, at distances of from thirty to forty feet from each other lengthwise of the vessel, and at heights not exceeding from eight to ten feet above each other, and to place the lower ones just above the level of the heads of the floor timbers in midships, and just above the kelson at the head and stern, and to place the others over the former, at such heights as named close up to the underside of the deck. And, where the vessel contains more than one deck, place a row of the thermometers close under, and another row upon each deck. And, where necessary for letting down and taking up the thermometers to and from the stations designated, attach grooves made of narrow battens to the sides and each end of the vessel of just sufficient size for passing the thermometers up and down, by means of a small flexible copper wire, or other convenient means, free from any obstruction by goods; and, where necessary for the same purpose, continue the grooves to the deck or upper deck, and

Grooves against the sides of the vessel on the inside for letting down thermometers where goods are stowed.

make small apertures in the decks for passing the thermometers through the same. Also let down thermometers to the like depths or levels in the lattice-works of carpentry before mentioned.

Thermometers, where to be placed on the outside.

On the outside of the vessel place a thermometer at the entrance of the shaft, and place others on deck immediately over those that are below in the interior. For greater quickness in taking the observations, it will be useful, where not opposed by inconveniences outweighing the advantage, to attach to the sides of the vessel above water, at places immediately opposite to where the thermometers above the level of the water line are placed in the interior, small grooved cases open in front, and of just sufficient length and width for receiving and holding other thermometers; which place in the same accordingly. Where no such cases are provided, it will be necessary, on taking observations, to suspend thermometers in the situations designated, and to keep them there as long as is necessary for them to attain the temperature of the particular place. Protect the thermometers wheresoever placed from the direct action of the sun's rays.

Thermometers not to be too sensible.

The thermometers used should be such as will bear being taken from their respective situations to be inspected, without undergoing any perceptible change in the temperature indicated by them. Having provided and placed the thermometers as directed, take observations with them as often as any material change of temperature, in such circumstances as the vessel is placed in with reference to the climate, the state of the weather, the time of the day or night, the number of the crew, and the kind of cargo on board, is found by experience liable, or at all likely, to take place; and in the meantime, till such experience is acquired, take observations every hour. By means of other thermometers, take, as accurately as practicable, and as often as the temperature of the water is found liable to any material change, observations of the temperatures of the water at the several depths on a level with the bottom of the vessel, and with the thermometers in the interior below the level of the water line.

Comparing the temperatures.

Compare the temperatures at each place of observation at the sides of the vessel at the outside, with the temperatures at the corresponding places or levels within, at the opposite side of the

timber; and compare the temperatures at the different places on deck, or on any inner deck, with the temperatures at the under side thereof; and compare all these with the temperature where the outer air enters the shaft. These comparisons being made, when such a difference of temperature is found at the opposite sides of the timber of any part of the vessel, as can be lessened or removed by the introduction of the outer air, in its actual temperature, into the interior of that part of the vessel, and by passing it off after circulating therein, the same, subject to the general rules hereinafter stated, is to be introduced and passed off accordingly.

When and how to introduce air of a lower temperature.

When the introduction of colder air is called for, the moveable part of the shaft is to be raised above deck at least sufficiently high for its apertures, with the shutters, to be above the deck, and for its lower end to clear all the apertures in the fixed part; and, in general, it will be advisable to raise it to its full height. And, on such introduction of colder air, it should be observed as a general rule, to keep the other fastenings, or entrances into those parts of the vessel into which it is introduced, close shut, except when it is required to open the same for the necessary uses of the vessel.

Regulating the aperture for admitting colder air into the shaft.

The quantity of colder air to be admitted for the whole of the interior, is to be regulated by lowering the working shutter or shutters of the shaft, to a greater or smaller extent, in proportion to the quantity of air required for the whole; and the quantity to be admitted to each particular part is to be regulated, in like manner, by drawing out the hatches in the admitting trunks, in such part, to a greater or smaller extent, according to the quantity of air required. And the quantity required, and the regulating of the apertures for its admission, will depend on, and are to be judged of, generally, first, by the greater or smaller difference of temperatures in the interior and at the outside, and the quantity of heat (if any) generated in the interior; secondly, by the more or less expanded state of the outer air itself by heat; and, thirdly, by the outer air being dry, or being more or less charged with moisture. The colder and moister the outer air may be, the smaller will be the quantity of it required; and the smaller will be the bulk of it for the quantity; and the smaller, consequently, will be the

requisite sizes of the apertures for its admission. But for exactly regulating the sizes of the apertures in each particular case, attention is to be paid to the quickness or slowness of the lowering of the temperature on the entrance of the air; and care is to be taken not to reduce the temperature in any part of the interior below that at the outside of the same part. To prevent the temperature of any part from being brought too low, return the hatches sufficiently far back into the admitting trunk for the desired purpose.

When the vessel is provided with admitting trunks, situated at different heights or levels, one over another, draw out, for admitting colder air, the hatches situated nearest to the lower part, or level, of the part from which the passing off of heat is required.

The temperature in any inclosed place being seldom, or never, exactly the same in every part, and the temperatures at different parts of the outside of the hold, or any other part of a vessel, being liable to still greater differences, study to make the general temperature of any inclosed place in the interior approximate the mean of the temperatures at its outside; and, where the exact mean is not attained, make the temperature of the interior approximate nearest to that at the outside, where water is in contact with the timber; and, where no water is in contact with the timber, make it approximate nearest to the temperature at the outside over head; and, where practicable, keep the temperature in such parts of the interior as are below the level of the water line, a little higher than that of the water, rather than endanger its being lower; and keep the temperature, immediately at the underside of any inner deck, a little lower than the temperature immediately over it, rather than higher. And where the air, either in the interior or at the outside, is much charged with moisture, bring the temperatures the nearer to an equilibrium; but, where practicable, preserve the air in the interior the drier, and keep it of rather the higher temperature. And the reason for seeking to keep the air in the interior the drier, and of rather the higher temperature, is, that where air of a higher temperature, in contact with timber, is much charged with moisture, the heat forming the excess of temperature therein above that at the opposite side of the

timber, will pass through, or leave the air to penetrate and enter, such timber much more rapidly than it will pass through, or leave, dry air; and it will consequently penetrate, and pass through, such timber with a proportionably smaller difference in the temperatures at its opposite sides. And hence it follows, that, when the air in any part of the interior is dry, and of a higher temperature than that at the outside, a greater difference of temperatures at the opposite sides of the timber may be permitted than where the warmer air is charged with moisture, without the like danger of causing heat to pass through the timber. And keeping the temperature in the interior the higher, will preserve the timber safe from the passage of any current of heat through it, from the outside, into the vessel. And where both the air in the interior of the vessel, and the timber in its interior, are dry, and a regular, although a slow, circulation and change of air and passing off of heat are kept up, the temperature may be kept considerably higher in the interior than at the outside, in any part of the vessel where, for the comfort of the crew, such a considerably higher temperature may be desirable.

Valves to be seen to be in proper working order.

Whenever colder air is to be introduced into any parts of the interior, the admitting and discharging valves for such parts must be seen to be in proper order for working, and must, if necessary, be made properly to work; that is, to yield to the pressure of the air, by substituting thinner and more flexible paper, or other light elastic substance, as before mentioned, than what may happen to be therein, and thereby lessening the resistance to the passage of air through the valve.

Introduction of warmer air.

When the temperature of any part of the interior is lower than that of the outer air or water at the same level, and, as respects any such part of the interior as is below the level of the water line, when the water at the same level is not warmer than the outer air at the apertures for the alternate passing off of heated air, and entrance of warmer air, for such part of the vessel, the temperature of such part may, by introducing the outer air, be raised as near to an equilibrium with the temperature at the opposite side of the timber as necessary. And such warmer outer air is commonly to be introduced, as before mentioned, through such last mentioned apertures, the valves whereof are to be taken out for the purpose. But if it be only

When the outer air is warmer than a particular part of the interior, and as warm as the water.

the lower part of the hold into which the introduction of warmer outer air is required, it will be most convenient to introduce such air through the shaft, and admitting trunks, as also before mentioned. And, in every case of introducing warmer air, it is to be caused to enter the vessel by removing the colder air already in the interior, up through the descending trunk, and out of the vessel, by one or other of the means, in that behalf, before described; and, for this purpose, use such of the apertures, in the descending trunk, for receiving the colder air, as are situated most nearly at the same level with, and not lower than, the part the temperature whereof is to be raised. And when that part of the vessel, the temperature whereof is to be raised, is situated immediately underneath a quarterdeck, poop, or forecastle, or in any other part at a distance from such descending trunk, with another part intervening of a temperature already sufficiently high, make use of a hose, as before described, for more speedily removing the colder air. The operation of removing the colder air, so long as the temperature at the outside remains unchanged, is to be continued till a quantity of the warmer air has been introduced, and passed off, sufficient to raise to the height desired the temperature, not only of the air, but, of the other substances contained in the particular part of the vessel, the temperature whereof is to be raised.

Where the temperature of the outer air is higher than that of a particular part of the interior, but not so high as that of the water.

When the temperature of any part of the interior, situate below the level of the water line, is lower than that of the water at the outside, at the same level, and the temperature of the air at the apertures of the discharging valves for heated air for such part, or at the entrance of the shaft, is at the same time lower than that of the water, but somewhat higher than that of such part of the interior, raise the temperature thereof, so far as it can be raised, by the introduction of the outer air, in the manner before mentioned. But no part of my said invention is directly adapted to still farther raising the temperature, in such case, to a level with that of the water. And I have purposely abstained from endeavouring to invent, and directing, any thing as applicable for that purpose, because the case supposed need not be otherwise than of very rare occurrence, and it may in almost all circumstances be guarded against, by taking care not to

The invention not adapted for what. And why not.

introduce any considerable quantity of air of a lower temperature than the water at any given depth, down to a depth on a level therewith, and by introducing air, at the hottest time of day, into such parts of the interior, when the vessel is approaching warmer latitudes, or the weather is getting hotter so as to raise the temperature of the water; and because, under such circumstances, any machinery for the introduction of heat, artificially produced from a fire, into such parts of the interior, would, by its expense, and the room it would take up, compared with the rareness of the occasions on which it would be required to use it, and the benefit it could produce, and by the risk of doing harm therewith, for want of apportioning the quantity of heat with sufficient exactness to the quantity required, be, in my judgment, on the whole productive of more disadvantage than good.

General qualification.

In such of the directions, which I have above given, as relate more particularly to the precise or exact situations, sizes, or dimensions, of any of the before mentioned alterations in the vessels, or of any of the apparatus and machinery before described, or to the situations and distances at which to place the thermometers from each other, or which relate to the degree of approximation of the temperatures immediately at the opposite sides of the timber, and in all the directions, generally, which relate only to the extent of the application and putting in practice of my said invention, I am to be understood as giving directions with the view to the most perfect and complete application thereof, and to giving it the most extensive and thorough reach of operation, according to the best of my judgment, without meaning, or intending to be understood, that my said invention will be either wholly, or greatly, ineffectual, unless all such directions be literally, and in the fullest extent, complied with; and, on the contrary, the same may, and will, be commonly very effectual, provided a reasonable degree of care and attention be bestowed in following the directions given, notwithstanding the nicety and exactness pointed and aimed at, in the matters just referred to, be not to the fullest extent observed and put in practice.

Having now particularly described and ascertained the nature of my said invention, and in what manner the same is

to be performed, I here, for guarding against being construed to claim as new therein, and as comprised within the power, sole privilege, and authority, granted by the said letters patent, any thing which is not new, and cannot lawfully be comprised within the said grant, repeat my declaration made at the commencement of this instrument of specification of my said invention, that the same consists in the making and manufacturing of the before described combination of the before described alterations in the vessels, and of the before described apparatus and machinery for the pnrposes before described, and not in the separate manufacture of any of the separate parts thereof. And although I believe several of the separate parts thereof to be new, and to have never heretofore been invented, found out, or practised, by any person whatsoever, I do not claim being entitled to any exclusive power, or any sole privilege or authority, under the said letters patent, in relation to the separate manufacture, or the separate use, of any of the separate parts in the said alterations, apparatus, and machinery, or to the manufacture or use of any combination of particular parts thereof, which may, before the granting of the said letters patent, have been combined made or used for the objects or purposes aforesaid, or for any other objects or purposes. But I claim the full power sole privilege and authority granted by the said letters patent, against any persons whomsoever making, using, exercising, or vending, for the objects and purposes aforesaid, either the whole of the said combination, or any combination of any two or more of the separate and particular parts thereof, which have never, before the granting of the said letters patent, been invented or found out and combined, or practised combined, for the objects or purposes aforesaid, or for any other objects or purposes. In witness whereof, &c.

INDEX.

AIR, an unperceived circulation of, in a room having a fire-place, in summer time, Page 119
a circulation of, goes on in a close shut vault, when heat is either entering or leaving it, 23, 24. 29
how caused, *id.* 27, 28
a brisker circulation, with a change of the air, on throwing the door open, 27, 28
the current of air, in such case, when the outer air is the colder, enters at the lower and passes out at the upper part of the doorway, *id.*
the direction of the current reversed when the outer air is the warmer, 30
colder, ceteris paribus, heavier than warmer, 53. 89
but it is so only ceteris paribus, 95
heat readily both enters and leaves, with differences of temperature, 80
comparatively slow passage of heat through air downwards, where, 21
moist, the more rapid passage of heat into or out of, 56, 57
dry, the comparative slowness with which heat leaves it, 54. 56
the velocity with which air rushes through a key hole, &c. into a room moderately air tight, with a fire in it, 52
the continued entrance of, into a room and passing of it off up the chimney relieves the heat from the necessity of passing through the timber of the wainscot, &c. 53
a regulated supply and change of hotter or colder, on

board ship, by the author's patent invention, for preserving vessels from dry rot, &c. Page 79
And see tit. Invention.
Chimnies, with fixed or revolving tops, for discharging heated air from decked vessels, 96, 97
principle of construction of, *id.*
centre of gravity of revolving top, 97
Conjecture supererogatory, as to how heat in passing through timber causes dry rot, 43, 44, 45
See tit. Heat.
Copper, the copper on coppered ships hastens their decay by dry rot, 70
but the hurtful effect of, mitigated by putting brown paper between it and the timber, *id.*
the brown paper lessens the quantity of heat that passes through the timber, *id.*
Dry rot, the cause of, is a current of heat, more or less rapid or considerable, passing through the timber, 1. *passim.*
narrative of the discovery of;
two underground vaults described, 4
the large size of one of them, *id.* 5
a large quantity of heat required to enter or leave it sensibly to alter its temperature, *id.*
a new door put up in, *id.*
wine deposited in, *id.*
a weekly account kept of its changes of temperature, 6, 7, 8, 9
alternate changes in the moisture or dryness of the different parts of, noticed, 6
its range of temperature in the course of the year, 8, 9. 20
difference between its temperature and that of the outer air in the hottest and coldest days, 6, 7
the new door become rotten, in four or five years, 9, 10
the dryness of appearance of the rotten part, 10
its very centre completely rotten before any outward appearance of decay, 11
inquiries into the cause of; and
rejection of the following possible causes:
wet deposited against the door, 10, 11
the air, 11

Dry rot, *continued,*
want of air, Page 11
mere want of circulation of air, *id.*
foul air, *id.* 12
light, 12
darkness, *id.*
a high temperature, *id.*
a low temperature, *id.*
the true cause discovered, 13
rejection, subsequent to the discovery, of other possible causes, viz.
changing from wet to dry, or the contrary, 33
fungus, 46, 47
insects, 37. 49
the current of heat must be more or less rapid or considerable, 51. *passim.*
continued in the whole a considerable time, 39. 51. *passim.*
a large quantity of heat in the whole necessary, 15. *passim.*
but the necessity of a current of heat passing quite through the timber, only a general proposition, 38, 39
arguments of the cause assigned being the true cause, viz.
1st. A very large quantity of heat in the whole passed through the vault door. *See tit. Timber, tit. Vault, tit. Water.*
2nd. None of the before supposed and rejected causes the true cause, 32, 33
no other cause than that assigned comes directly into contact with the inmost parts of the timber, 10, 11
3rd. The reasonableness of the cause assigned by analogy to known effects of heat on various other substances. *See tit. Heat.*
4th. A possible objection arising from the comparative rareness of dry rot in rooms in which fires are kept, anticipated and answered. *See tit. Dwelling houses.*
the progress of the decay dependent, ceteris paribus, on the rapidity of the passage of the heat, 63. *And see tit. Timber.*

Dry rot, *continued*,
the length of time it passes in the whole, Page 63
the kind of timber, *id.*
the quality of the timber for its kind, *id.* 64
Dust, denser clouds of, just before a heavy shower in summer, 95
Dwelling houses,
rooms in, having fire-places, comparatively seldom affected with dry rot, 50, 51
timber exposed to the heated air of, gradually becomes very dry, shrinks laterally, and opens numerous passages for the air, *id.* 53
the air, on entering, receives, and is expanded, and put into circulation by, and passes off with, the heat up the chimney, &c. 53, 54
little or no heat passes out through the door of, 55
the comparative slowness with which heat leaves dry air, 54. 56
the difficulty of keeping an old wainscotted room moderately air-tight and warm, 52
comparatively new houses more subject to dry rot than older ones, 55, 56
unperceived circulation of air in rooms with fire-places, in summer time, 119
Fungus, not the cause of dry rot, 46
not always present, *id.*
none on the author's vault door, 47
a single tuft of, appeared on, when, *id.*
but it soon died, *id.*
conjecture as to the cause of its dying, *id.* n.
when present, it may indirectly hasten the decay, and how, 47, 48
a mushroomy flavour given to wine by a mould growing out of the cork, 27
Garden-stuff frozen, effect of thawing it too quickly, 42, 43
Gate-posts, why they decay fastest at the surface of the ground, 34
Glass, newly blown, left to cool in the common temperature of the glass-house, flies into atoms, 41
annealing, what it is, *id.*

Glass, *continued*,
badly annealed always more subject to "fly" on heat entering or leaving it, Page 41
the best, liable to crack on the too sudden entrance or passing out of heat, *id.* 42
Goods on board ship, different kinds of, liable to damage by heat, 120
the damage to, in general, how caused, 121
comparison of a heating cargo with a heating hayrick, *id.*
the great importance of preserving the goods from, *id.*
the proper means of, *id.*
perforated battens placed between the packages, where necessary, 99
Hatchway insufficient for a circulation and change of air in a vessel, 68
Hayrick, the damage done by the heating of, caused for want of what, 121
Heat, the nature of, perhaps, not rightly known, 15
but no questionable positions respecting it necessary for the present subject, 15
its tendency to leave warmer to penetrate and pass through colder substances, 16
solid substances oppose resistance to its passage, 17
a certain difference of temperature, therefore, necessary to, *id.* 61, 62
the difference varies according to the particular substance, *id.*
the quantity that passes depends on what, 18, 19. *And see tit. Timber.*
the length of time it continues to pass, *id.*
leaving warmer air saturated with moisture to pass through a colder body, impassable to water, deposits water against its surface, 22. 25, 26. 29, 30. *And see tit. Water.*
issuing from a body wet on its surface, into colder air, takes up the water with it into the air, and dries the body, 23
the like where the body is wet in the interior, if it be sufficiently pervious to water for it to pass out, *id.*
the quicker passage of, into or from moist air, &c. 54, 55, 56

Heat, *continued*,
expands air entering a room having a fire in it, and passes off with it up the chimney, &c., Page 53, 54
he quick passage of, through timber is the cause of dry rot, 1. *passim*.
reasonableness of the argument of, supported by analogy to known different effects of heat on different substances; viz.
different effects of its more or less rapidly entering or leaving
glass, suffering glass newly blown to cool without annealing, 41
annealing, what it is, *id.*
steel, tempering, 42
frozen garden-stuff, too quickly thawing it, *id.* 43
meat, the like, 43
limb, the like, *id.*
different quantities of, required for producing the like effect on different substances; for instance,
melting,
mercury, 42
ice, *id.*
oil, *id.*
tallow or butter, *id.*
lead, &c. *id.*
the like to volatilize them, *id.*
the like for the growth of different vegetables;
a quantity of, which is insufficient for the growth of some, kills others by its excess, *id.*
supererogatory conjecture as to how the heat, in passing through the timber, works the decay, 43, 44, 45
Insects, not the cause of dry rot, 49
none on the vault door, *id.*
some worm-like, in wet rotten pieces of timber in the vault, 37
the decayed part of the timber apparently their food, but not the sound part, 49
Invention, the author's patent, for preserving decked vessels from dry rot, and goods on board from damage by heat, 79

Invention, *continued*,
the leading principle of, for the first object, is to maintain a sufficiently near approximation of temperatures to an equilibrium on the opposite sides of the timber, to prevent any quick passage of heat through it, Page 79
the means used are the introduction and passing off of a regulated quantity of the hotter or colder outer air, as the occasion requires, *id.*
why the air of the atmosphere is the instrument used, 80
why the quantity introduced is to be a regulated quantity, 81
means provided of introducing the air into particular parts, and down only to particular depths, at pleasure, *id.* 82
colder air, for passing off heat, to be conveyed down below the hotter without mixing with it, 85
warmer air to be introduced by removing the colder, 104, 105
heavy gases to be removed, 102. 105
Parts of;
alterations in the vessels, to open passages for air, 84
apparatus or machinery for introducing and passing off the air:
for introducing in general colder air to pass off heat,
a hollow shaft for conveying colder air down below the hotter, *id.* 85
a moveable part to the shaft, with apertures for the air, to stand, when raised, above deck, *id.*
the apertures furnished with sliding shutters to regulate the quantity of air admitted, *id.*
hollow trunks attached to the shaft to convey the air to the parts where required, 86
orifices in, for the air to issue from into the interior, *id.*
lateral trunks to where necessary, 86
sliding hatches to regulate the size of the passage to each orifice, 87

Invention, *continued*,
where an additional set of trunks, Page 88
but the introduction of colder air to average depths only practicable, or necessary, *id.*
the above mentioned apparatus not alone sufficient, 89, 90, 91
valves, new invented, to permit the air to pass in the required direction and prevent it from returning, 91
And see tit. Valve.
where to be placed, 93
chimnies over discharging apertures for heated air, with tops either fixed or revolving, to discharge the air in the direction of the wind, 96, 97
lattice works in certain cases for getting at valves situated below goods in a loaded ship, 98, 99
for preserving goods, perforated battens, in certain cases, for passages for air among the goods, 99
thermometers, to ascertain the temperatures at the opposite sides of the timber, 100
where to be placed, *id.* 101
the water, ascertaining the temperatures of, at different depths, *id.*
apparatus for introducing warmer air, &c. by removing the colder, &c. 105
a descending hollow trunk, with apertures, provided with doors, &c. at different depths in the interior, for receiving the air to be removed at different levels, at pleasure, *id.*
the air to be removed up through, by any adequate means; for instance:
a pump, 105, 106
a machine like bellows, 106
a fire in a close stove (in most cases), *id.*
dimensions of the pump, &c. *id.*
hoses attached to the descending trunk to receive the air nearer the ends of the vessel, in certain cases, 107
Working the invention:
warmer air, introduction of, what to be done on, 107

Invention, *continued*,
general rules for regulating the temperature on, Page 108, 109
where the temperature in the interior, if desired, may be kept considerably the higher, 109, 110
the absolute power of, to effect what, 111
a case in which a complete prevention of some considerable passage of heat through the timber, an impossibility, 110, 111
but the current of heat in, may be mitigated and its force broken and shared between different parts in succession, 111, 112
the invention more effectual than any thing else, 113
Motives for putting the invention in practice:
1st, the necessity of protecting vessels from the action of the cause of dry rot, 114, 115
the predicament of every vessel at present, 115
every vessel that has ever perished by decay, at whatever age, has perished by the same cause that in its swifter ravages has latterly been called dry rot, 116
the short-lived existence of the largest men-of-war, 75
the heavy expense in the navy for "materials" and "artificers' wages," 75
the little durability at the best of timber in shipping hitherto, compared with its durability in various other situations, 116, 117
the probable prolongation of its durability by means of the invention, 117
2nd, incidentally ensuring the proper ventilation of the vessel, with the view to its healthfulness, 118
this hitherto not rightly understood, *id.*
the healthfulness of a vessel a question of money to the owner, 119
3d, the preservation of goods on board from damage by heat, 120
this an object of great importance, *id.*

Invention, *continued*,
various kinds of goods liable to such damage, Page 120
how the damage, in general, is caused, 121
possible arguments against using the invention considered and answered, 122, &c.
the invention is not expensive, 122, 123
the room taken up by, does not exceed what, 123, 124
the attendance of one man, in general, sufficient, 123
the questions for a ship owner to put to himself, 125
inducement to an immediate putting of the invention in practice, *id.* 126
Iron. *See tit. Metals.*
Limb frozen, rubbing with snow the proper mode of thawing it, 43
mortifies by suffering heat to enter it too quickly, *id.*
Meat frozen, becomes putrid if thawed too quickly, 43
Meshing tub not a durable utensil, 60
Metals, heat passes rapidly through them on a difference of temperatures. 62. 70, 71
placing them in contact with timber hastens its decay, where, *id.*
And see tit. Timber, tit. Water.
Moisture, heat enters or leaves moist substances more quickly than dry, 54, 55, 56. 62
And see tit. Timber, tit. Water.
Mouldiness, an experiment to render cheese mouldy, but which spoiled its flavour, 25, 26
the flavour of wine spoiled, on decanting, by a mould or fungus growing out of the cork, 27
Navy, the fleeting existence of ships in, 74, 75
anecdotes concerning, *id.*
quarterdecks of vessels in, sometimes rock like new-made hayricks, 75
the little durability of vessels in, one of the author's mo-

Navy, *continued*,
tives for taking up the subject of dry rot as a matter of business, Page 74
Navy estimates, heavy items of charge in, for "materials" and "artificers' wages" 75, 76
the necessity for, attributed by the mover of, to a wrong cause, 76
Paint, metallic, hastens the decay of timber, in what situations, 71
Palliatives of the evil of dry rot, theoretical, and possibly also practical, 77
placing in contact with timber substances more impervious than itself to heat, *id.*
but dangerous on board ship, and at the best only palliatives, *id.*
another sort of palliative, but unsafe, &c. 78
a quality essential to the natural and proper remedy, *id.*
Paper. *See tit. Valve.*
Patent, specification of, 137 to 169. *And see tit. Invention.*
Plates, explanation of the, 127 to 135.
Ship, a, is peculiarly exposed to the cause of dry rot, 65
a ship building, how soon it begins to be exposed to it, *id.*
first exposed on a change of weather from colder to warmer, 66
more exposed on being decked or covered in, 68
the more exposed the closer it is kept shut, 69
so, the larger the vessel, *id.*
so, by a heating cargo, or a numerous crew, *id.* 70
washing decks, *id.*
the copper on a coppered ship, *id.*
but the hurtful effect of, lessened by what, *id.*
iron or other metal bolts, if where, 70
metallic paint, where, 71
the parts of, which first decay, 71
the necessity of artificial means of protecting ships from the cause of dry rot, *id.* 114, 115
the author's invention for, and the importance of putting it in practice. *See tit. Invention.*

Steel, the temper of, depends on the quickness or slowness of cooling it, Page 42

Temperature. *See tit. Heat.*

approximation of temperatures to an equilibrium. *See tit. Invention.*

Thermometer, 100. *And see tit. Invention.*

Timber, an organized body subject to causes of premature decay, 115

the importance of preserving timber in shipping from dry rot. *See tit. Ship, tit. Invention.*

the quick passage of heat through it causes the dry rot, 1. *passim.*

where there is wet on or in the timber, the passage of the heat is the more rapid, 56

the interior, if wet, may therefore be the first decayed, 56, 57

heat may pass through timber lengthwise, instead of crosswise, *id.*

timber shrinks laterally by dryness, and creates passages for the air, where, 51, 52

the kind of situations generally in which a current of heat will be passing through timber, 58, 59, 60

where heat will be carried off from, by a circulation of air, instead of passing through it, 60, 61

the principal circumstances on which the quantity of heat that passes through timber in a given time depends, are

the difference of temperatures on its opposite sides, 62

the dryness or moisture of the air on each side, 56. 62

the wetness or dryness of the timber, whether on its surface, or in its interior, 57. 62 *And see tit. Water.*

the kind of substance generally in contact with it, as, whether it be metal or stone, &c. 62

the thinness or thickness of the timber itself, *id.*

the kind of timber, *id.*

Timber, *continued*,
its quality for its kind, Page 62
its position with reference to the direction or setting of the heat towards it, *id.*
the length of time it continues to pass on each occasion, and consequently the quantity that passes in the whole depends, *ceteris paribus*, on
the quantity or supply of heat on the hotter side, 19. 62
the quantity of colder substances on the opposite side, with their permeableness to, and capacity for retaining heat, 62, 63
the progress of the decay dependent on what, 63
certain circumstances on which the superior quality of, for its kind, appears principally to depend, 63, 64
Time, a considerable length of, requisite for working decay by dry rot, 13. 39, 40. 51. *passim.*
Trees, the largest, supposed, while growing, sometimes to split open by heat forcing its way out, 41
Trial at law, arising from a vessel having quickly become dry rotten, 75
various erroneous opinions as to the cause of dry rot stated at the trial, *id.*
these formed one of the motives for the author's taking up the subject as a matter of business, 74
Valve, a new invented, to permit air to pass in a required direction, and prevent it from returning, 91
the principle of the invention, *id.*
the proper qualities of the working material of, *id.*
thin superfine writing paper recommended, 92
experiment with different sorts of writing and printing paper to try their power of resisting damage from water, *id.*
the sum of the moving force for working the valve, 94
tissue or silver paper, a suggestion whether it might not prove sufficient low down in a vessel, *id.*
Vault, two underground vaults of the author described, 4
And see tit. Dry Rot.

Vault, *continued,*
the large size of the larger vault, Page 4
its range of temperature in the course of the year, 8, 9, 20
a new door put up in, becomes dry rotten, 9, 10
a large quantity of heat passed through the door while it was decaying, as shown by the following considerations:
1st, a very large quantity of heat by turns entered and left the vault, 20
2nd, the comparative slowness with which heat can make its way directly down through a body of air contained in a close receptacle, 21
3rd, the thinness of the door compared with the thickness of the brickwork, *id.*
4th, the depositing of water against each side of the door by turns on heat passing through it into or out of the vault, 22
the depositing of the water, how caused, *id.*
5th, the drying of that side of the door out at which the heat issues, 23
the largeness of the quantity of water deposited against the inner side of the door accounted for, *id.* *And see tit. Water.*
a circulation of the air is constantly going on within, while heat is either entering or leaving the vault, 23, 24
how such circulation is caused, *id.*
a quicker circulation, with a change of the air, on throwing the door open, 27, 28. *And see tit. Air.*
a large quantity of water carried out of the vault by, on setting the door open in frosty weather, 28, 29
the temperature of the vault very much lowered by, *id.*
Vegetation, heat necessary to, 42
a quantity of heat insufficient for the growth of some vegetables, kills others by its excess, *id.*
heat supposed to enter by the process of, into the composition of the vegetable, and to form in a solid shape one of its ingredients, 44, 45

Ventilation, the proper ventilation of a vessel not hitherto well understood, Page 118
incidentally ensured by the author's patent invention, *id.* *And see tit. Invention.*
the proper ventilation of, with the view to its healthfulness, a question of money to the owner, 119
necessity of using right means to ensure, 68. *passim.*
a new invented valve, one of the means, 91
Vermin on board ship, 98
Water, on heat leaving air saturated with moisture to pass through a colder solid substance, is deposited against the substance, 22
Examples of;
deposited against the outside of a vault door, on heat passing through it into the vault, 22
inside of the door, on heat passing through it out of the vault, *id.*
iron staples in the crown of the arch, when the ground above is colder than the vault, 71
the brickwork of the arch itself on a more considerable difference of temperatures, *id.*
the underside of smooth boards placed in contact with the arch, 25, 26
the cross piece forming the upper part of a door frame supporting colder brickwork, and in contact with which warmer air was passing out, 29
bottles of colder wine, or any other liquid, 31
the highest bottles first, where, *id.*
the heads and clenched points of nails driven through a door or partition.—[*Note.* This was in the case alluded to, but not particularly described, in page 71]
deposited against these, sooner than against the wood. [The like.]
painted timber sooner than against timber unpainted. [The like.]
smooth timber sooner than against timber rough from the saw. [It so seems, from the same case.]

Water, *continued*,
the water so deposited with a small difference of temperatures, where, Page 30, 31
taken up again into the air, on the heat returning in the contrary direction, 23. 31
Water butt, never very durable, 59, 60
Wet rot, heat conjectured to cause the decay, in cases of, 33, 34. 37
but without there being necessarily any current of heat through the timber, 34
the most common instances of, are in gate-posts, &c., *id.*
the progress of the decay in, is gradually from the outer parts inwards, 35
instances of, in several pieces of timber, in the author's vault, 35, 36
water, by penetrating the timber, enables heat quickly to penetrate it, and again leave it, how, 34
Wine, a mushroomy taste imparted to, by a mould, or fungus, growing from the corks, an instance of, 27

THE END.

LONDON:
PRINTED BY THOMAS DAVISON, WHITEFRIARS.

00088510

Digitized with financial assistance from the
Government of Maharashtra
on 02 January, 2016